Heavy Rain Climatology of Upper Michigan

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What will be covered

- Overview of Heavy Rainfall events in Upper Michigan
- Study Methodology
- Brief case study Examples of each pattern type associated with heavy rainfall
- Composites of Patterns from NCEP/NCAR Reanalysis data

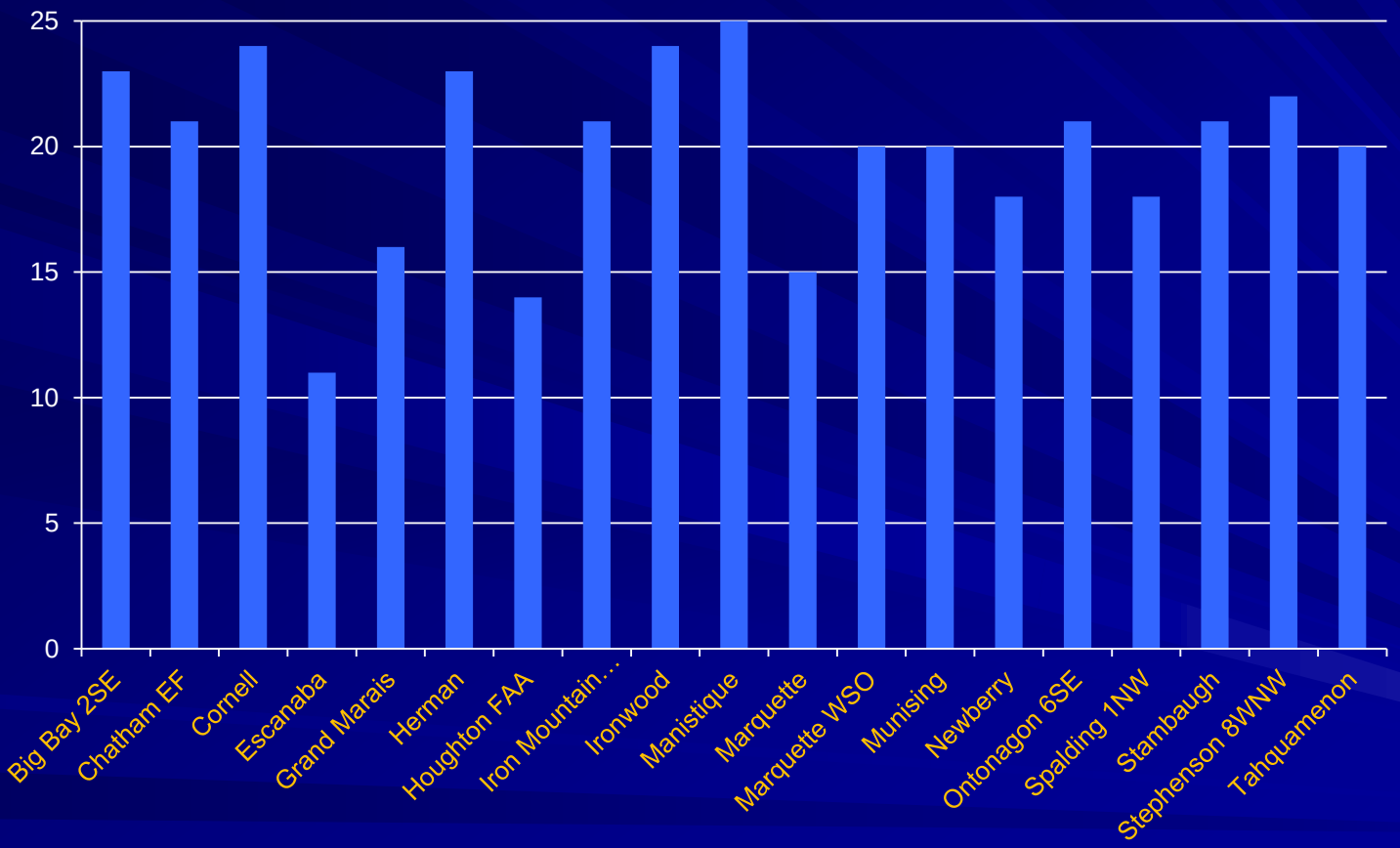
Top Rainfall Events In Coop Site Records (1888 to present)

Greatest amounts in 24 hour reporting period

	Location	Date	Amount
1	Ironwood	21 July 1909	6.72 inches (171 mm)
2	Ironwood	17 July 1942	6.70 inches (170 mm)
3	Big Bay	12 May 2006	5.93 inches (151 mm)
4	Ironwood	1 November 1909	5.61 inches (142 mm)
5	Kenton	14 July 1980	5.45 inches (138 mm)
6	Ishpeming	29 July 1949	5.35 inches (136 mm)
7	Grand Marais	26 October 1905	5.27 inches (134 mm)
8	Stambaugh	15 July 1999	5.20 inches (132 mm)
9	Marquette	12 May 2006	5.12 inches (130 mm)
10	Grand Marais	7 May 1908	5.08 inches (129 mm)
11	Ironwood	22 July 1909	5.00 inches (127 mm)

Location of observation sites used in the study

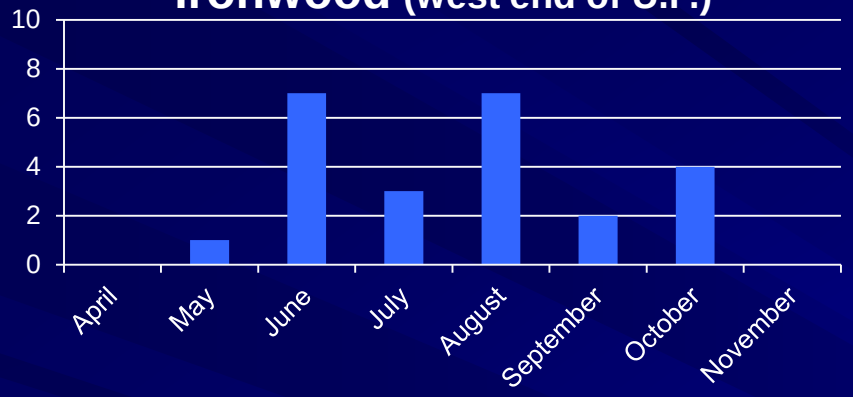
Events at each station
(1966-2009)



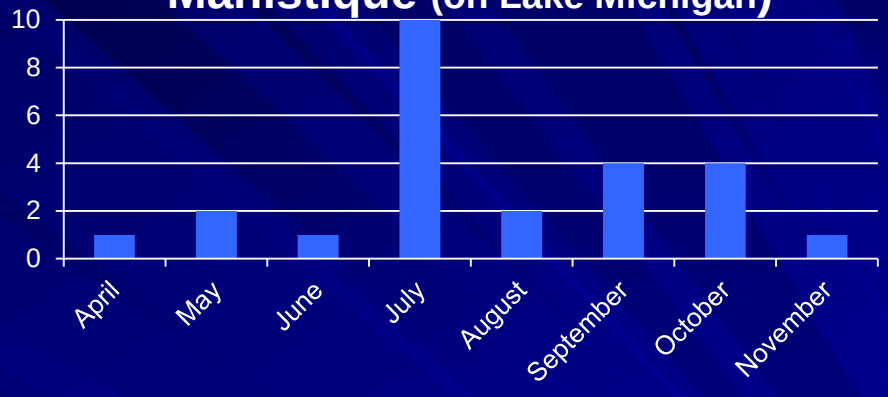
24 hour rainfall amounts of 2.00 inches (51mm) or greater

Events at selected stations by month

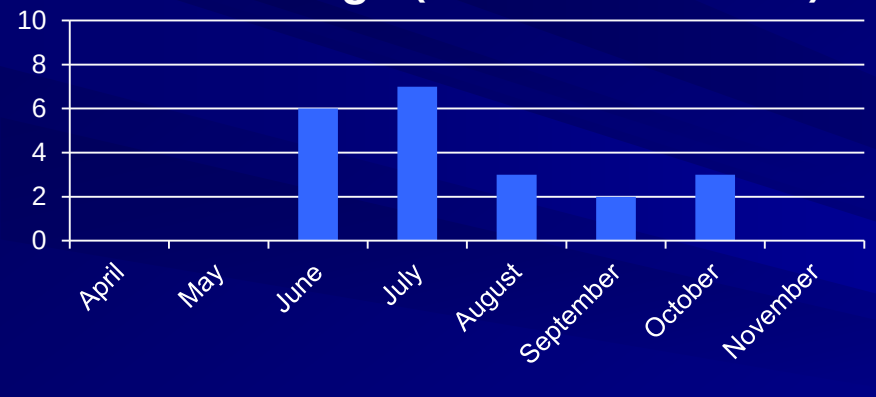
Ironwood (west end of U.P.)



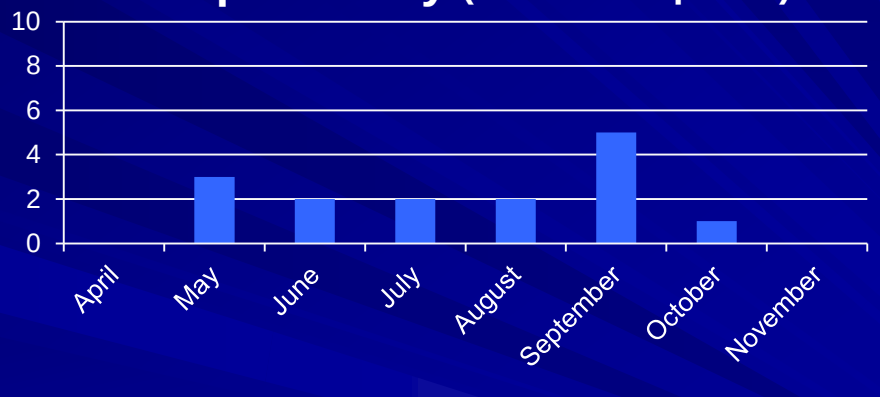
Manistique (on Lake Michigan)



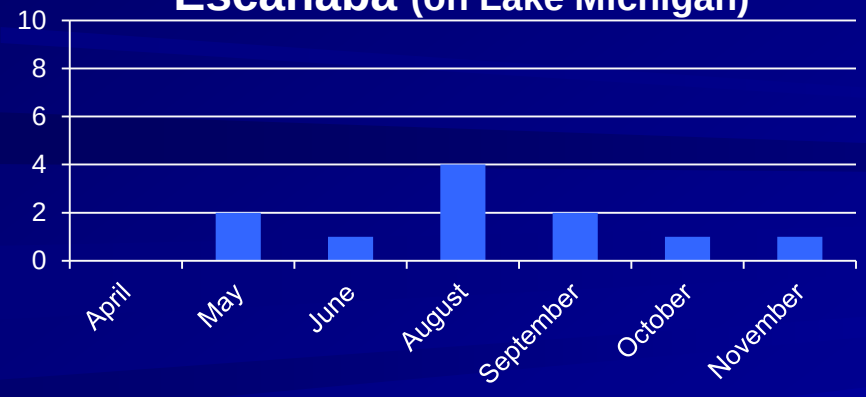
Stambaugh (Inland near WI border)



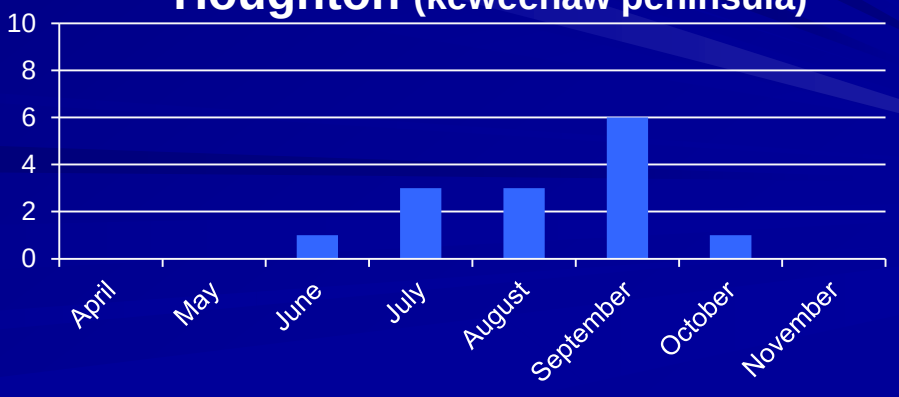
Marquette City (on Lake Superior)



Escanaba (on Lake Michigan)



Houghton (keweenaw peninsula)

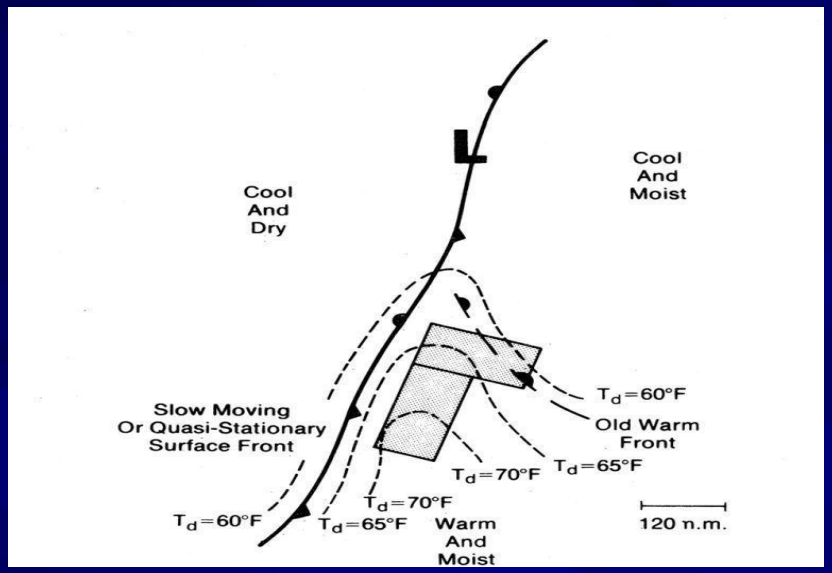


Methodology

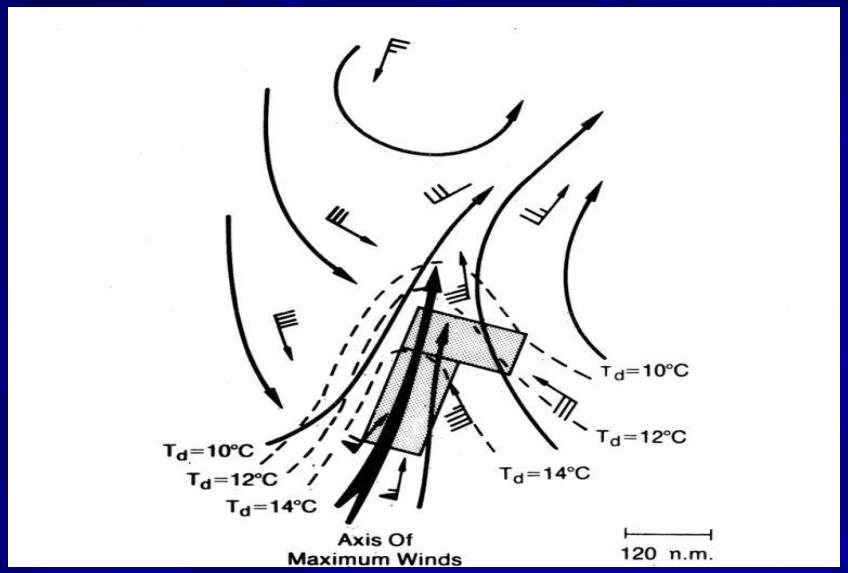
- 19 Sites used that had continuous data during the period from 1966 through 2009
- Rainfall events (rainfall amount of 2.00 inches or greater during a 24 period) obtained by query of Midwest Climate Center database
- Case designated if 2.00 inch or greater rainfall observed at two or more of the 19 designated sites. Cases on consecutive days were consolidated.
- Characteristics of each case were examined using NCEP/NCAR 6-hour reanalysis data and Daily Weather Maps
- Time of case (6 hourly) was determined when the precipitable water and instability values were greatest
- Cases could be classified similar to types described by Maddox (1979) in flash flood study. One additional type was designated.

Maddox Synoptic Type Flash Flood Event (Type 1)

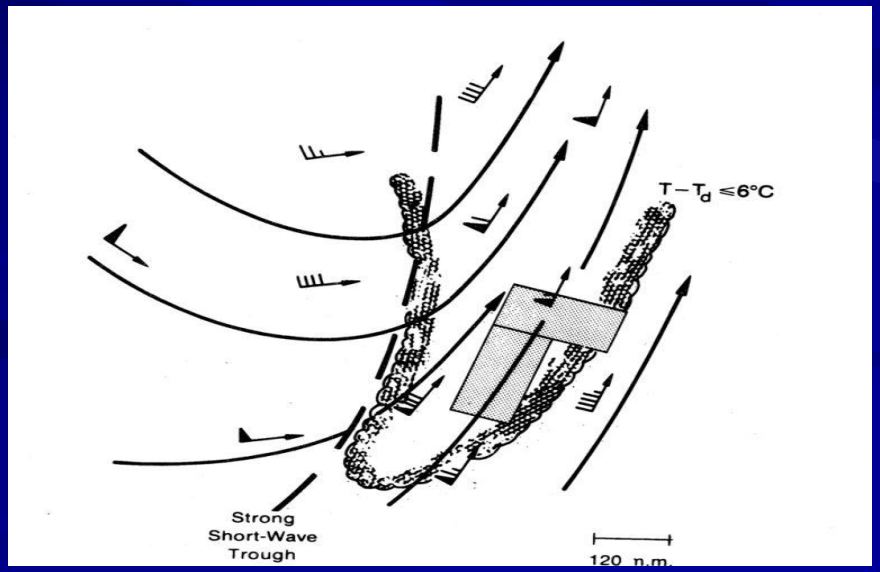
Surface



850 mb



500 mb



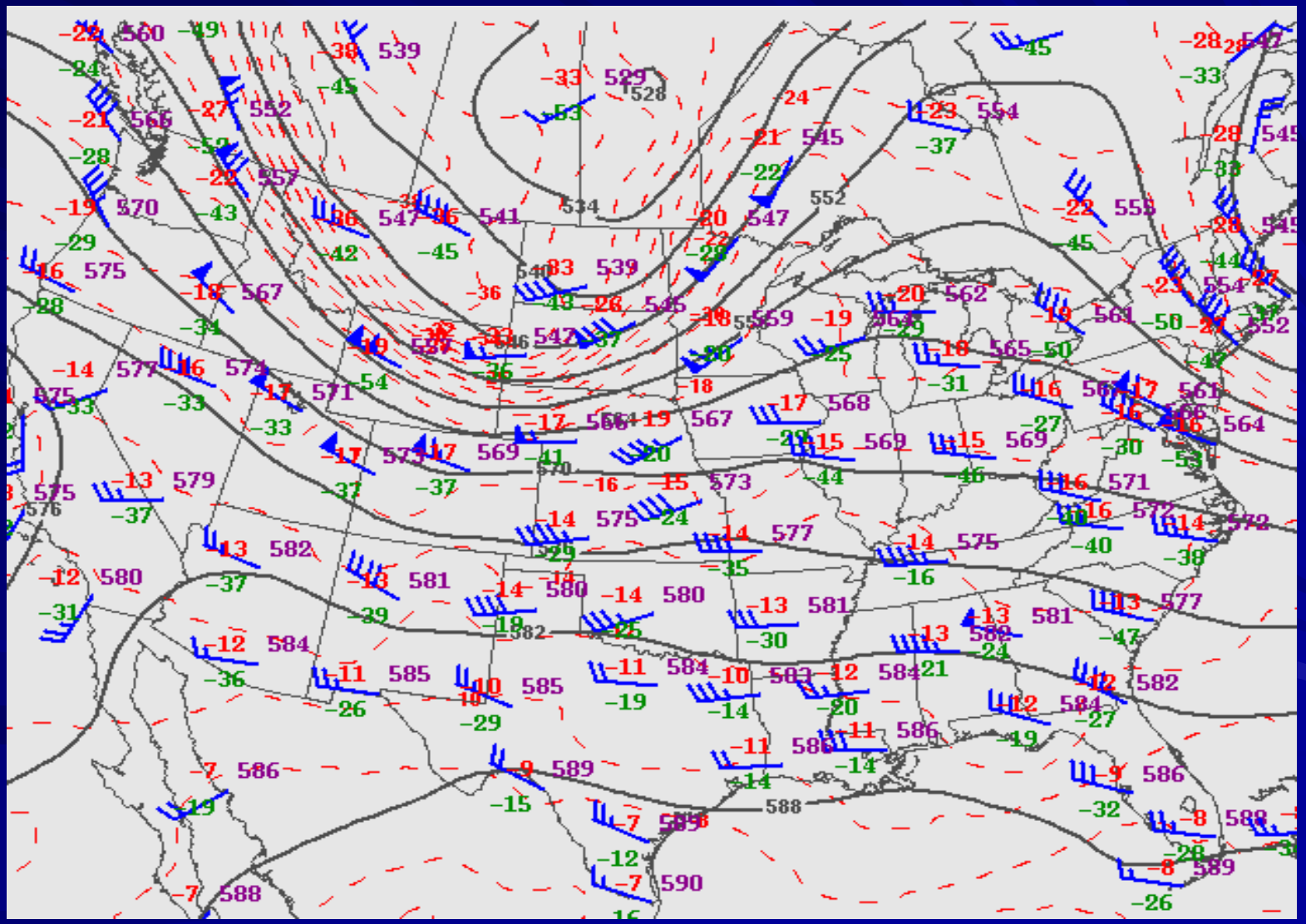
Maddox, et al. (1979)

Type 1 case
24 April 2002

- Strong progressive mid level trough
- North-South oriented surface front
- Heavy rain occurred to the east (in the warm sector) ahead of the front

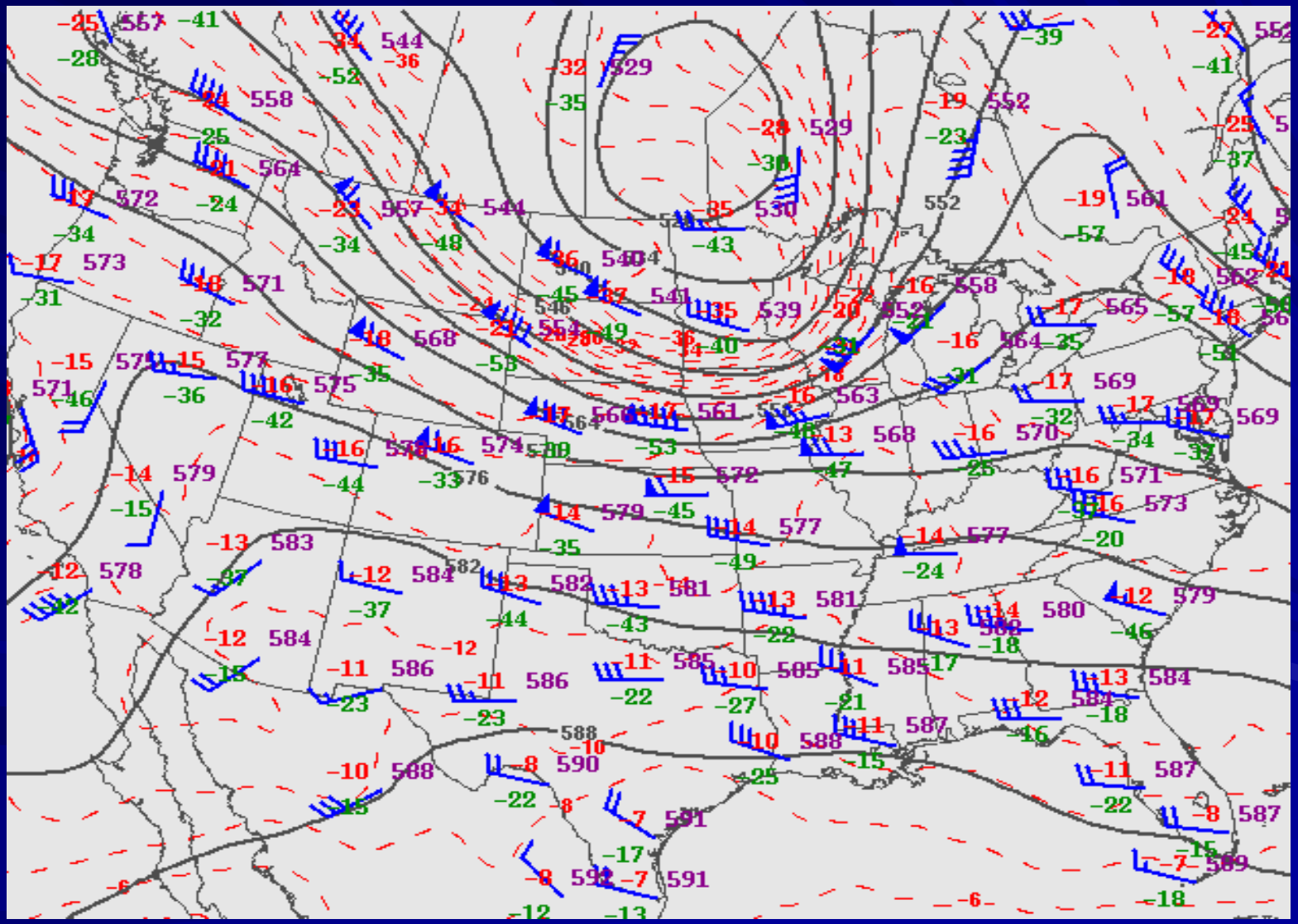
4/24/02 12z 500 mb

Obs, Heights, Temps

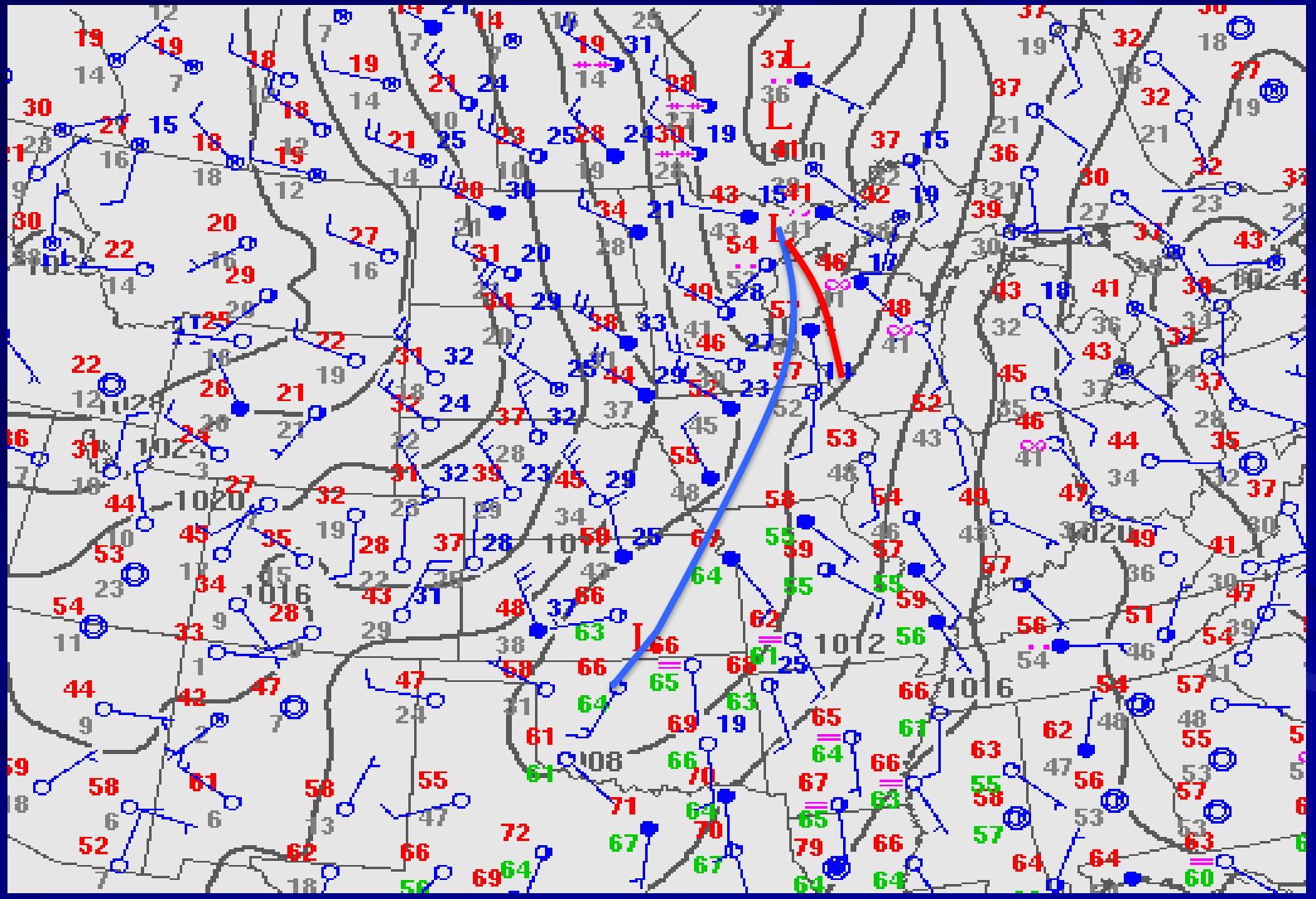


4/25/02 00z 500 mb

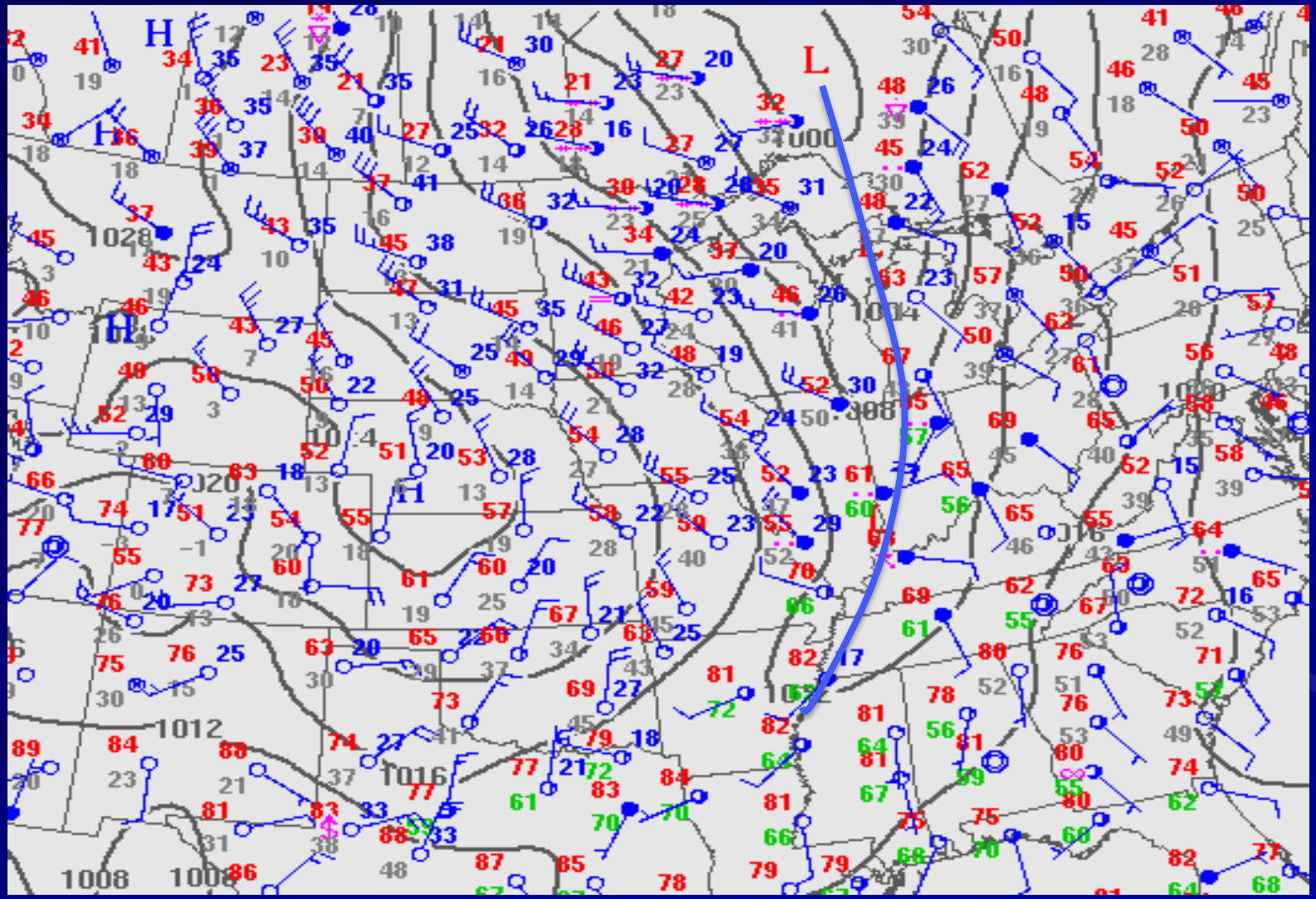
Obs, Heights, Temps



4/24/02 12z Surface Pressure and Obs

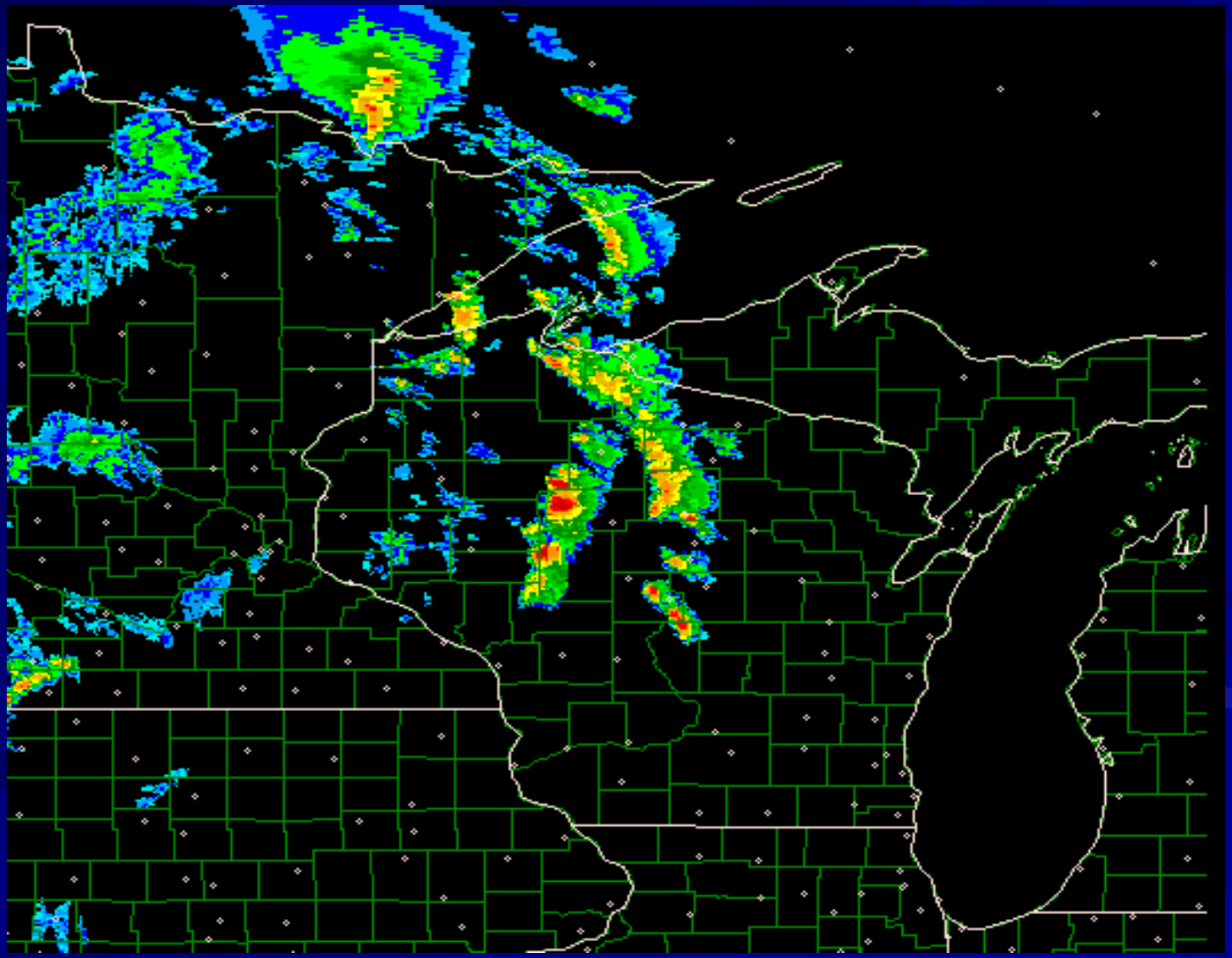


4/25/02 00z Surface Pressure and Obs

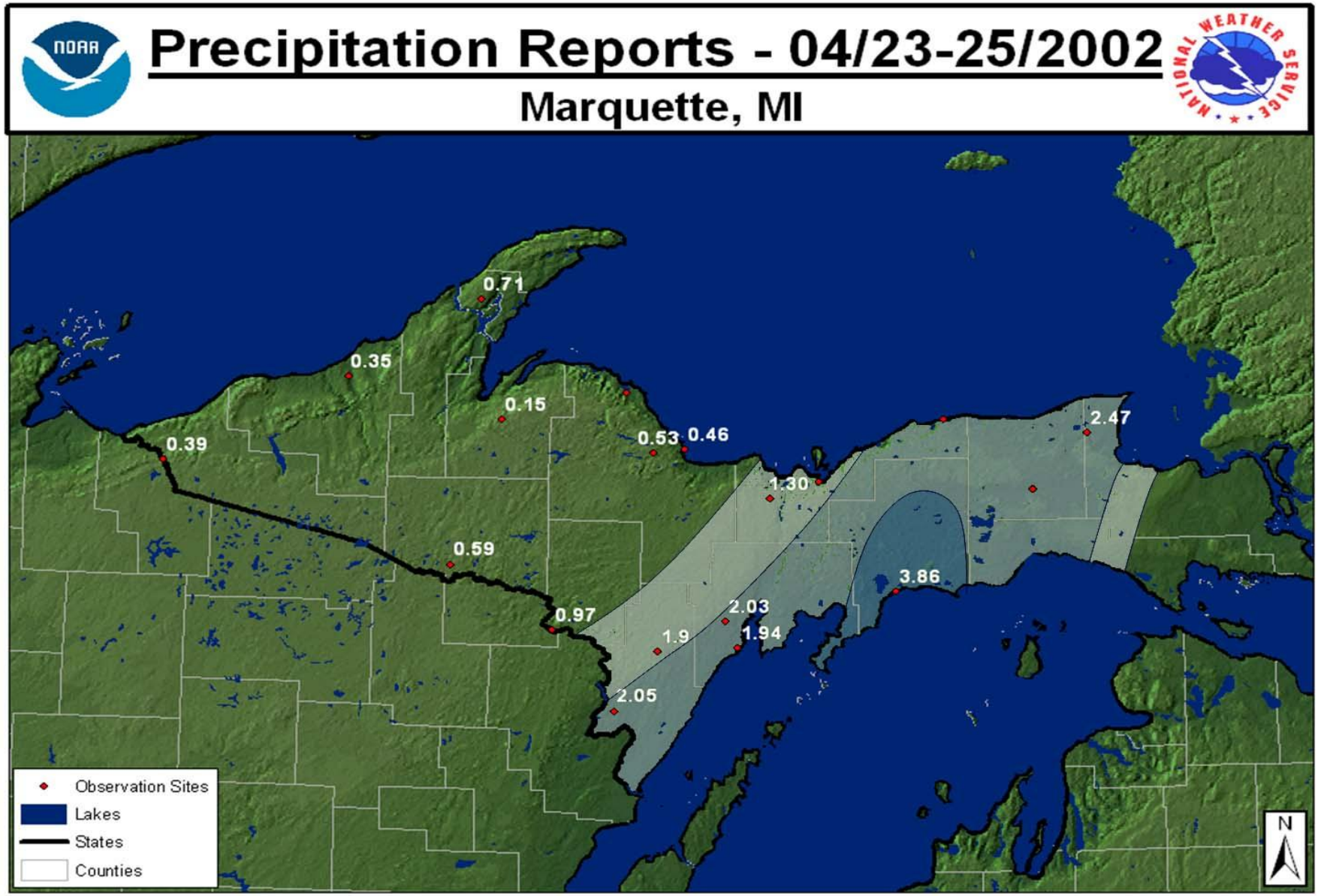


Composite Radar Loop 4/24/02 09z to 4/25/02 03z

(image interval 1 hour)

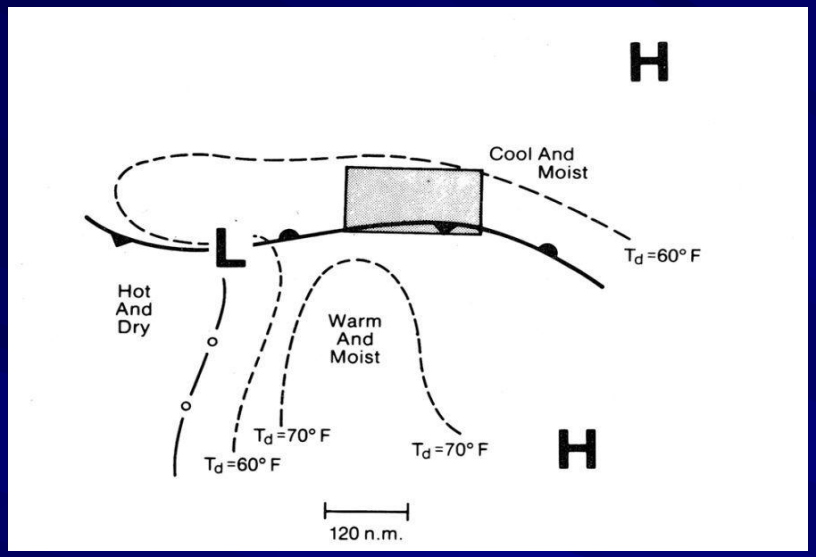


Rainfall amounts (inches)

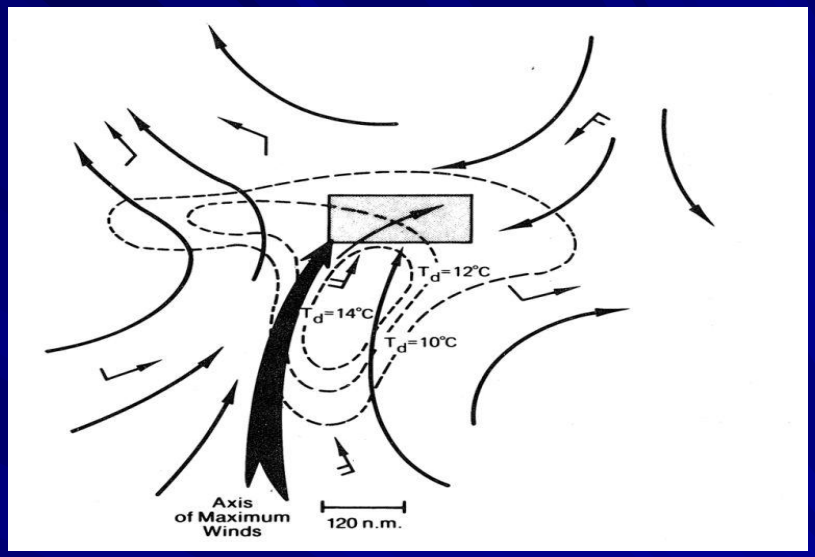


Maddox Frontal Type Flash Flood Event (Type 2)

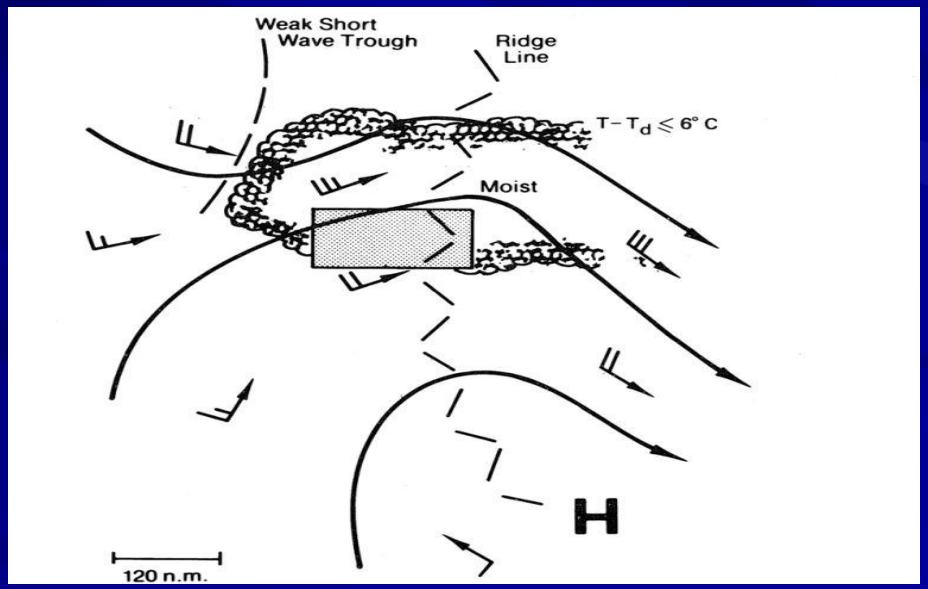
Surface



850 mb



500 mb

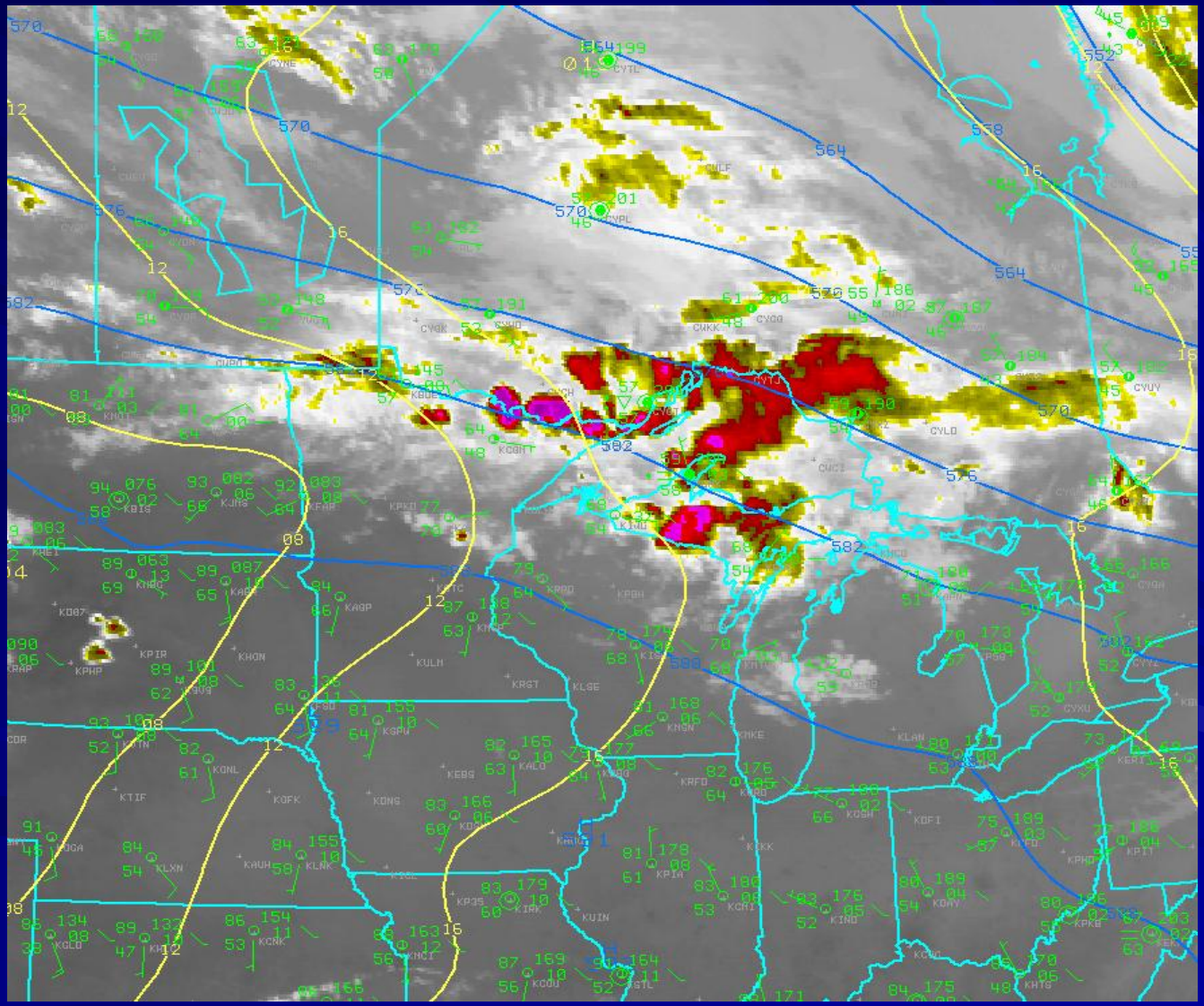


Maddox, et al. (1979)

Type 2 case
4 September 2007

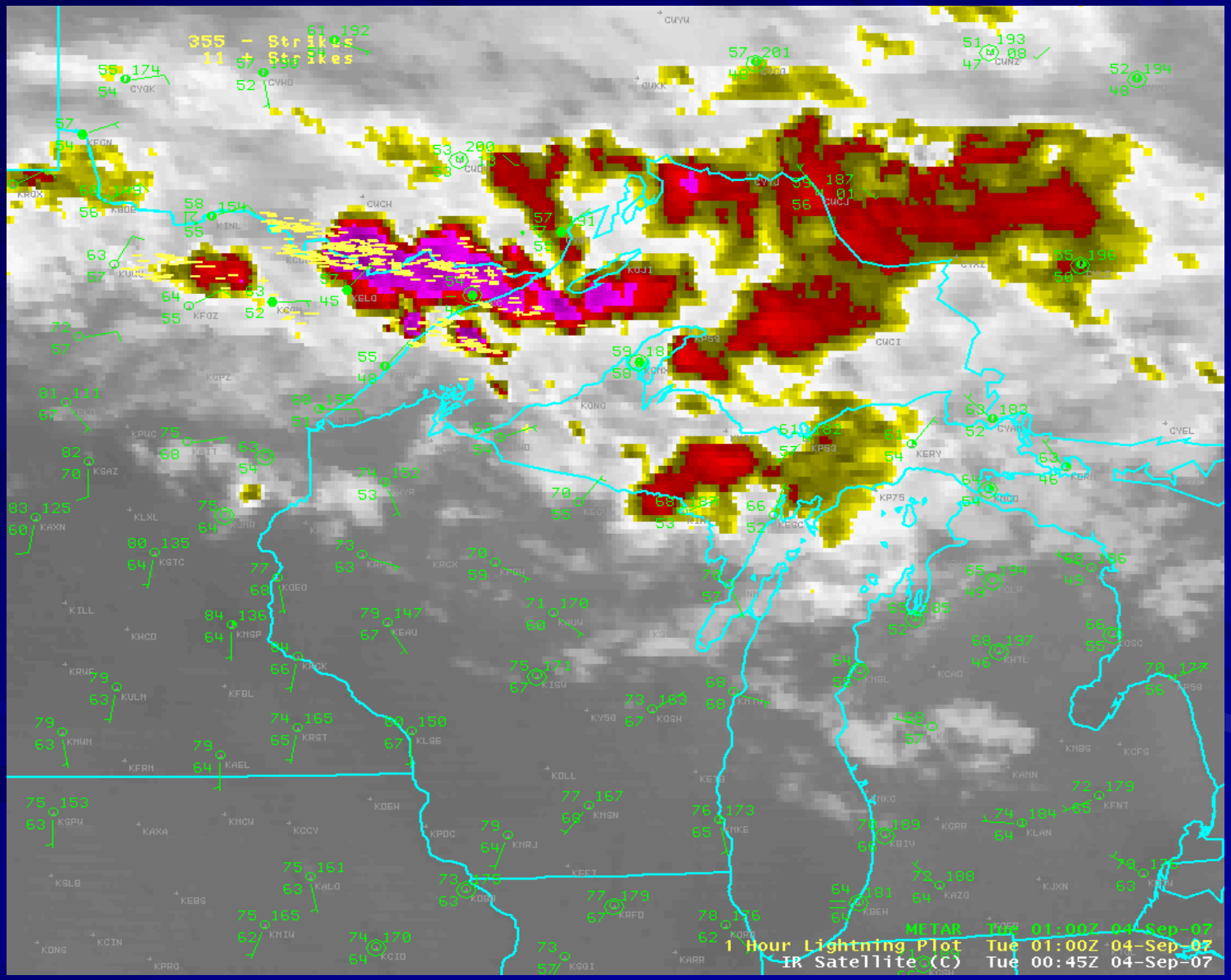
- West northwest mid level flow
- West-East oriented surface frontal system extending from low pressure over the northern plains
- Heavy rain occurred to the north or cool side of the front
- Frontogenesis played a large role

9/4/07 00z
IR Satellite, 500 mb height, MSL



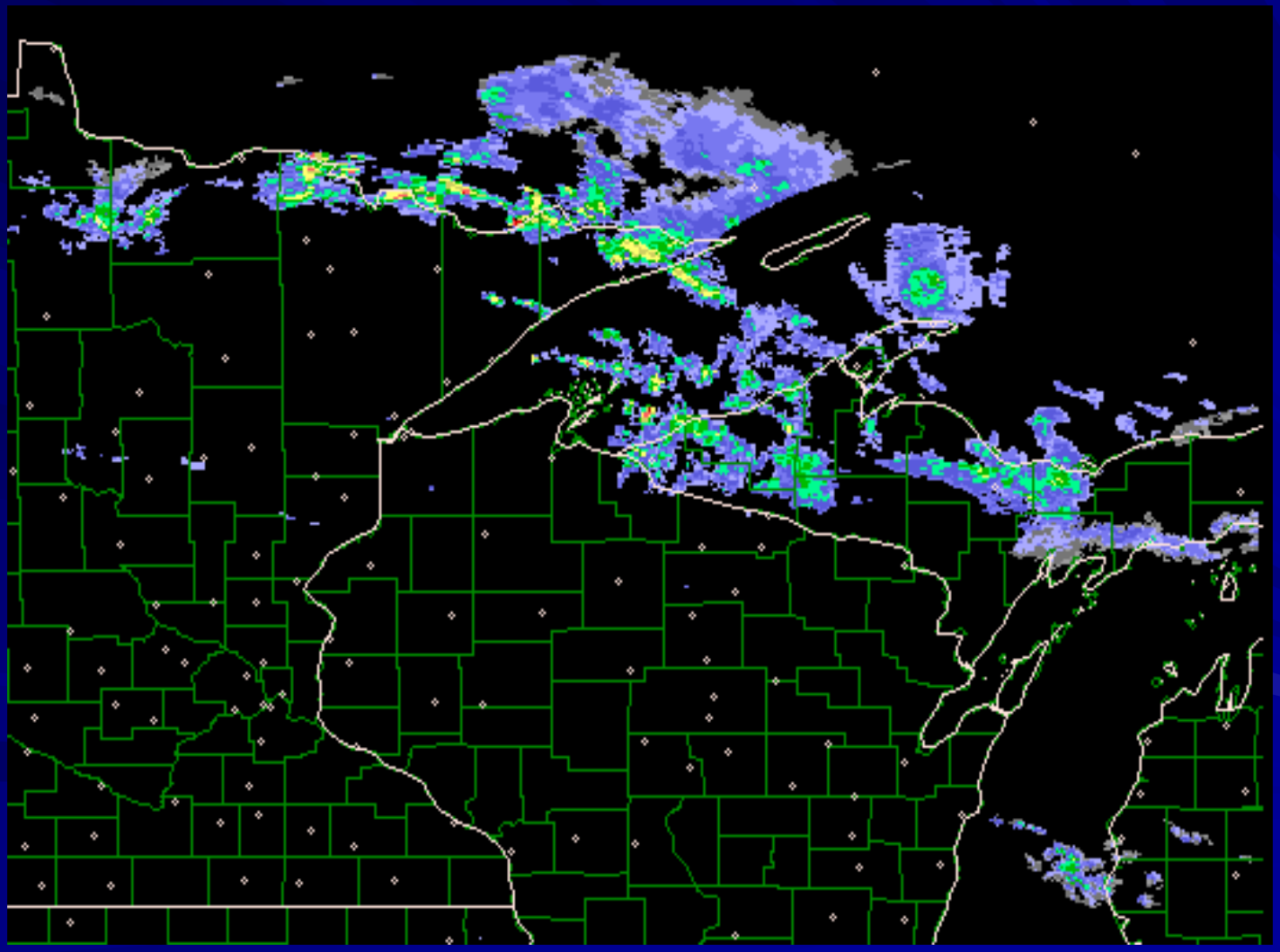
IR Satellite and 1 hour lightning loop 9/4/07 00z-18z

(image interval 1 hour)

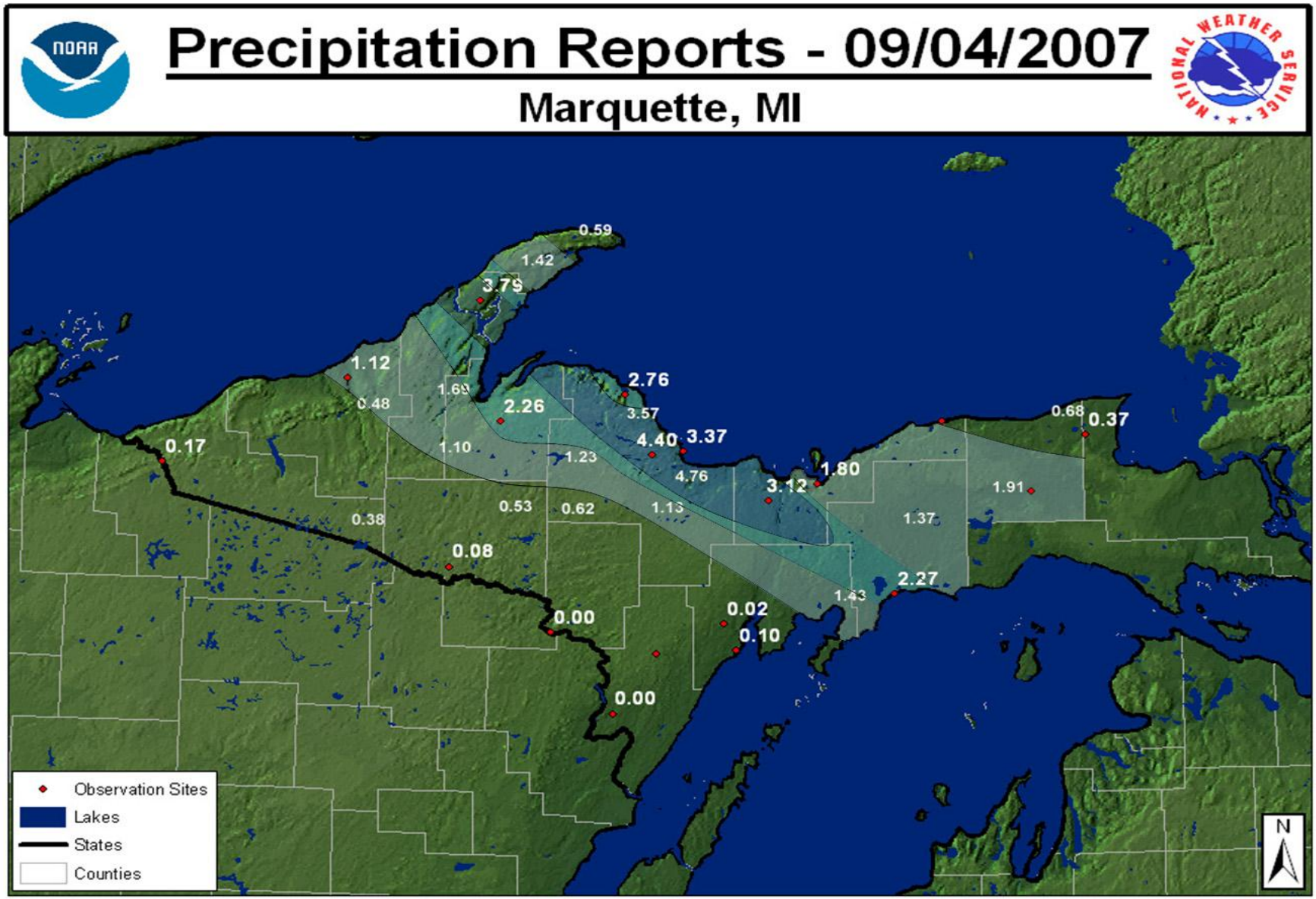


Composite Radar Loop 9/04/07 00z to 18z

(image interval 1 hour)

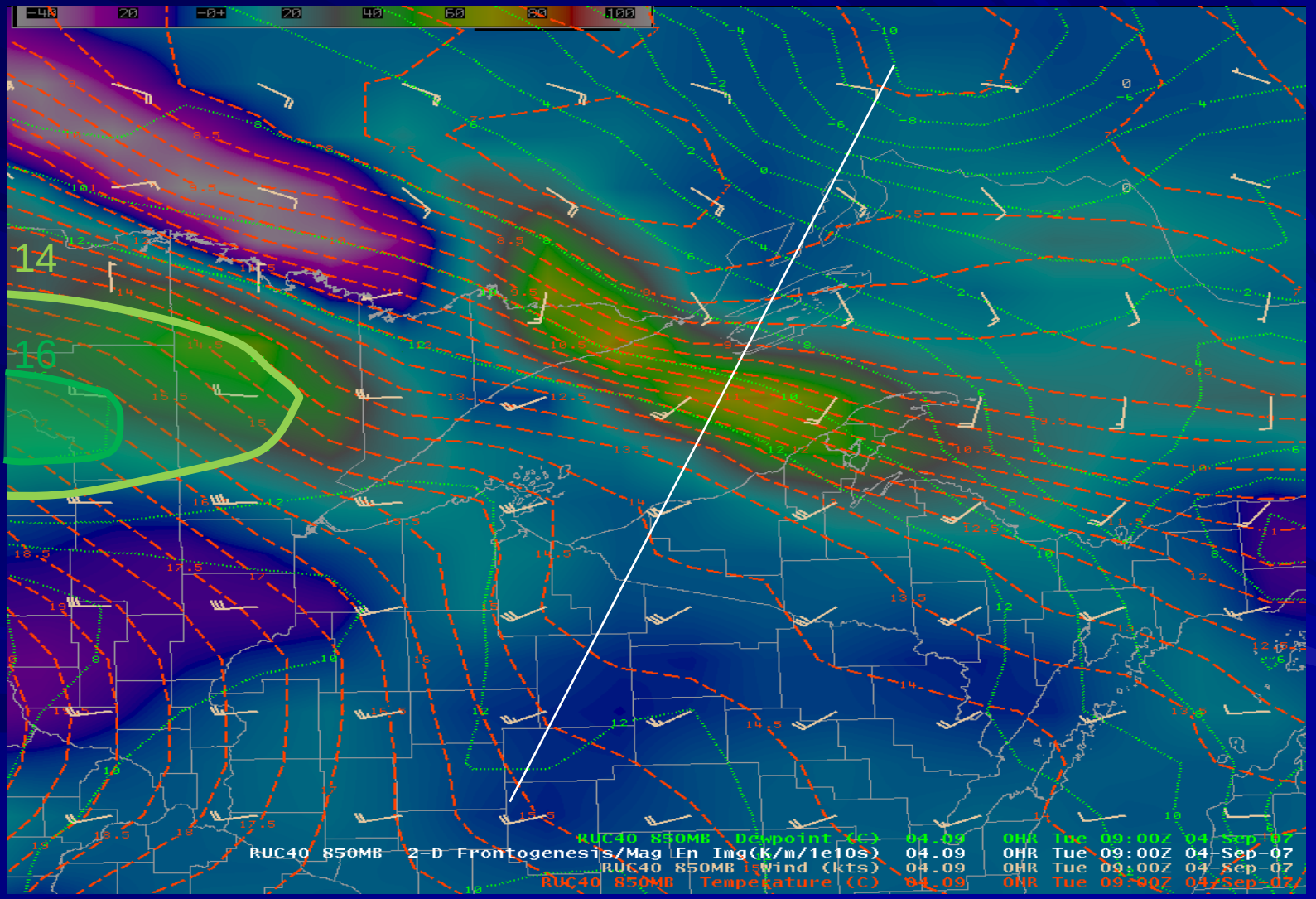


Rainfall amounts (inches)



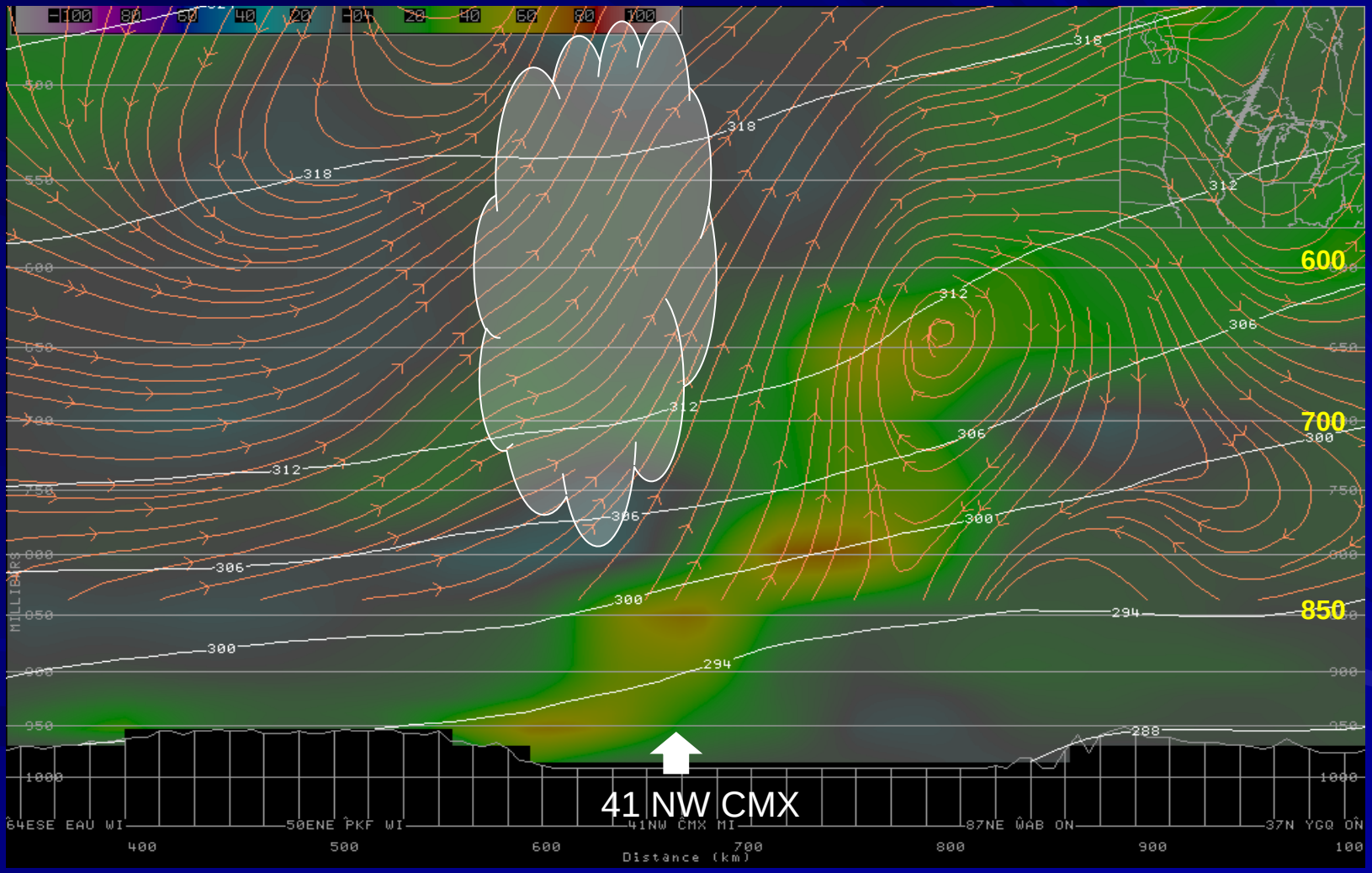
9/4/07 09z 00 RUC 00 hr fcst

850 mb wind, temp, dewpoint and 2-D Frontogenesis (image)



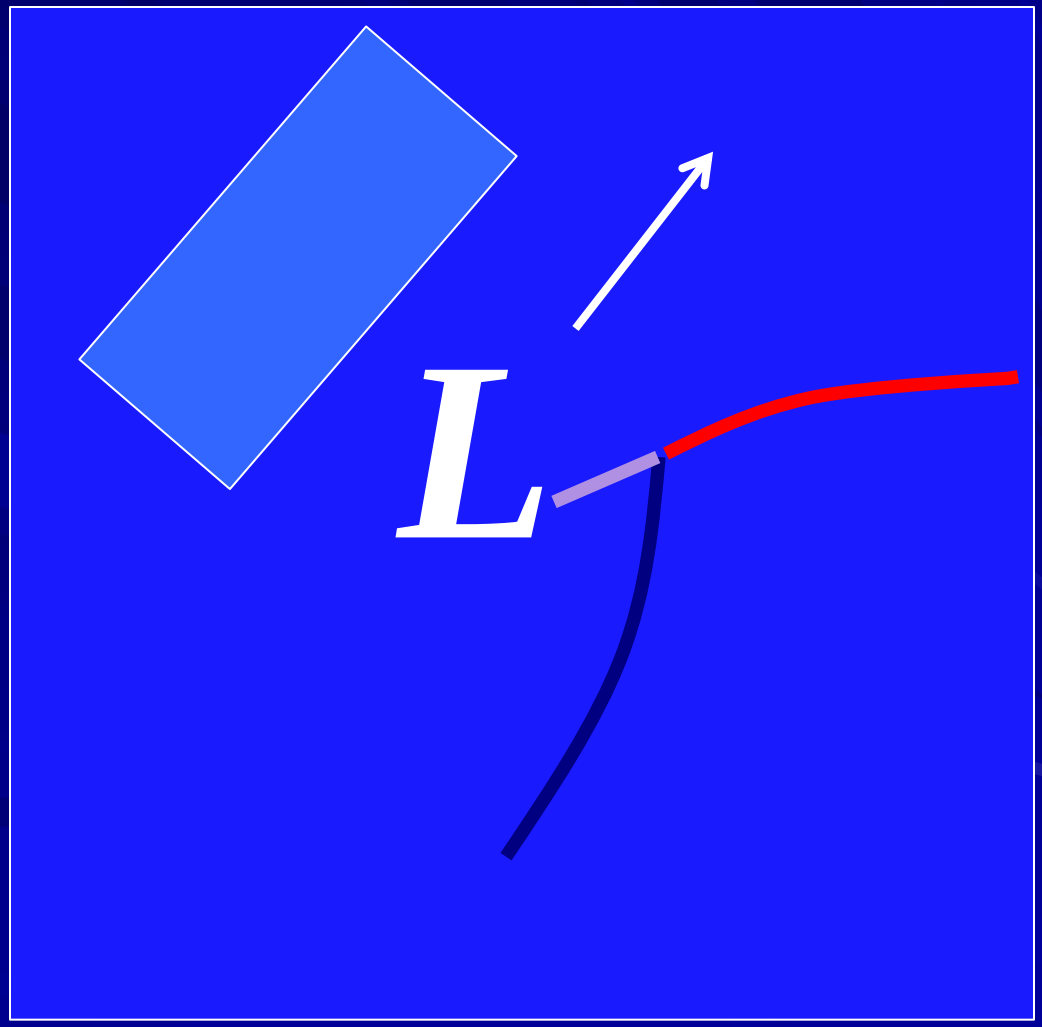
9/04/07 09z RUC 00 hr fcst Cross Section

2D-Frontogenesis(image), Theta, ageo vertical circulation



Type 3

- Strong surface low
- Heavy rain to the left of the surface low track
- 850-500 mb Frontogenesis / deformation region
- Trowal often present
- Terrain enhancement often plays a role

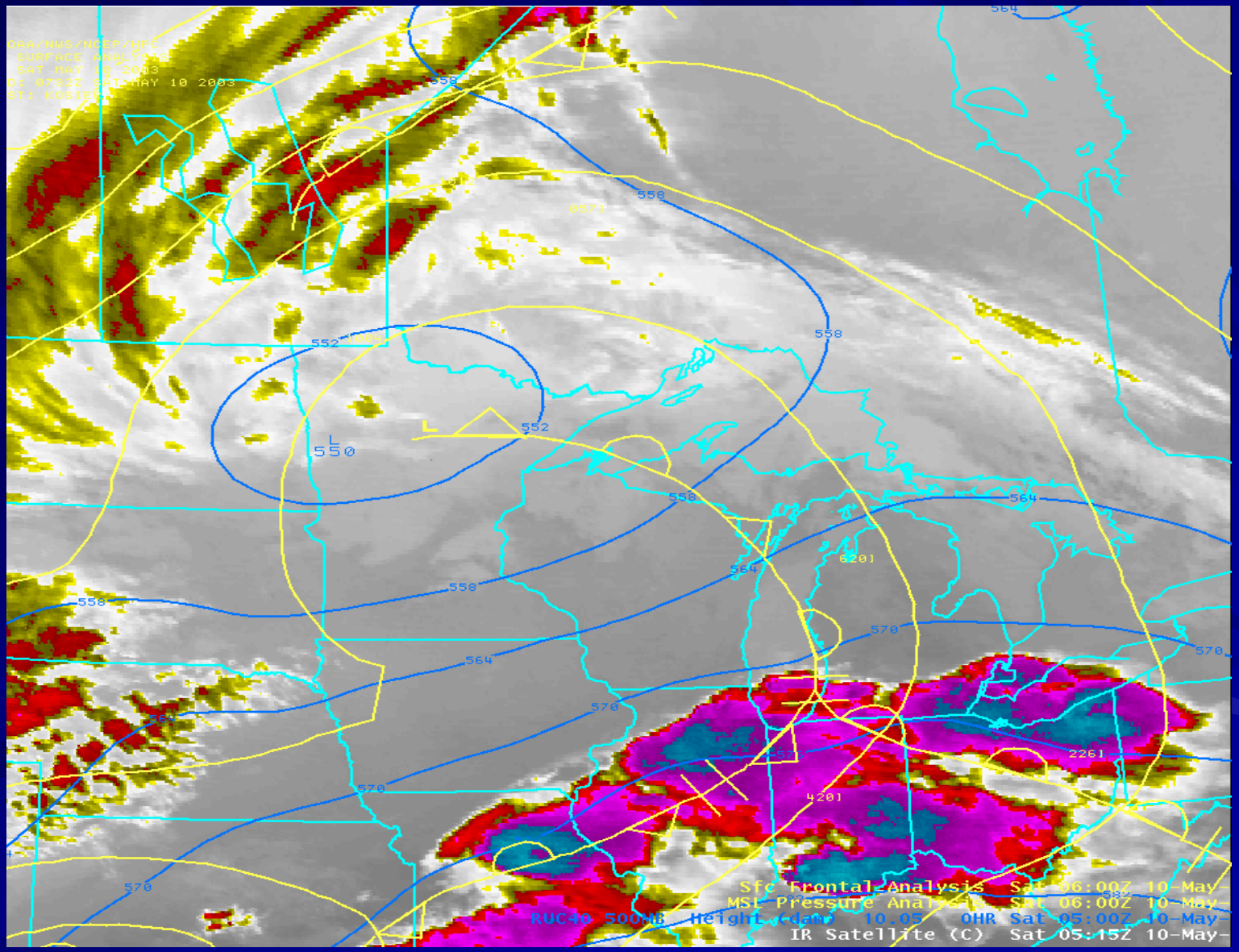


Type 3 case
10 to 13 May 2003

- Strong mid level trough deepened to a closed low
- Intensifying and occluding surface low moved to the northeast through central Wisconsin into eastern Upper Michigan
- Heavy rain occurred to the left of the low track typical of cold season precipitation events
- Trowal region developed and significant orographic enhancement occurred over north central Upper Michigan during the last half of the event

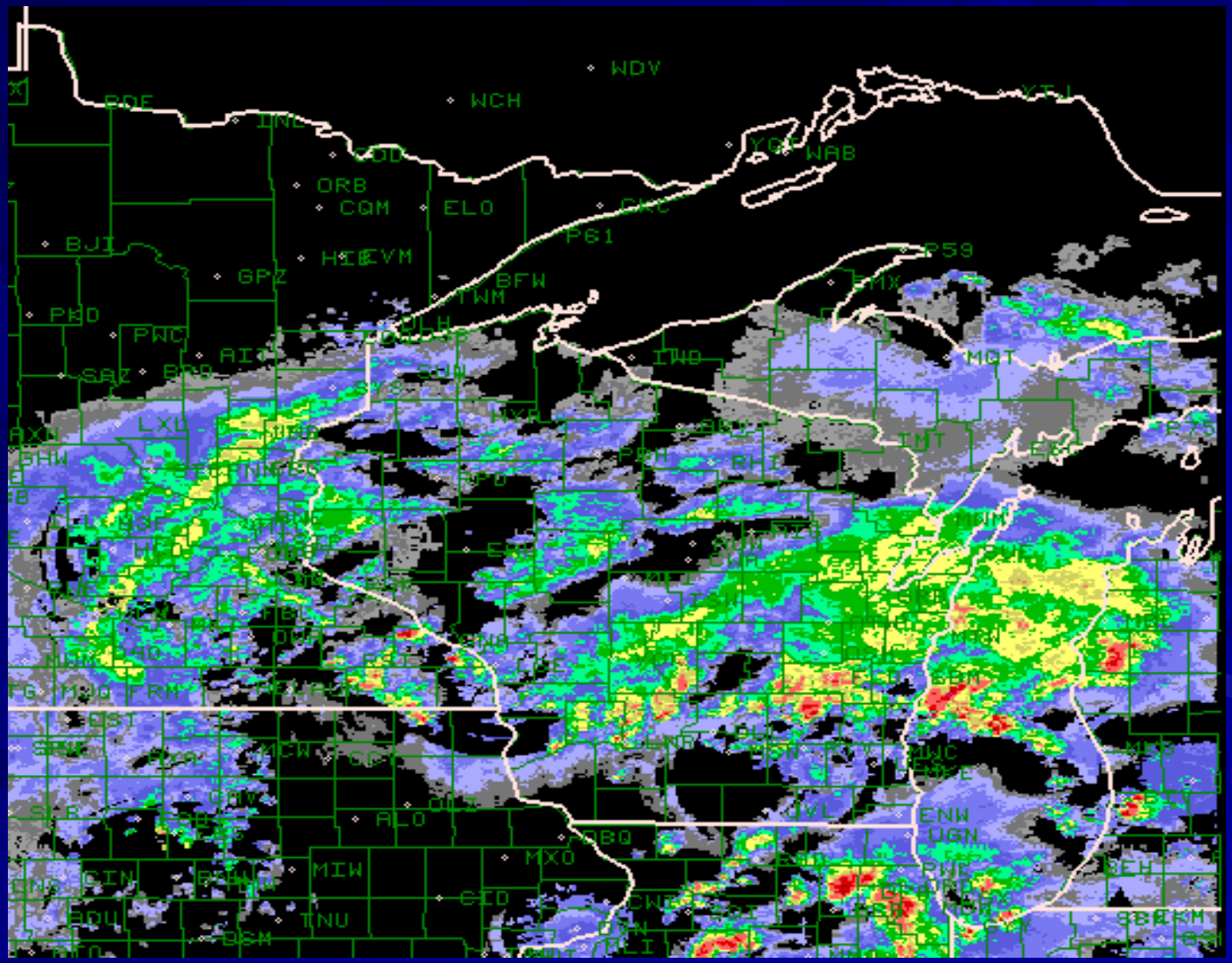
IR Satellite loop 05/10/03 06z to 05/13/03 00z

500 mb, surface analysis (image interval 6 hours)



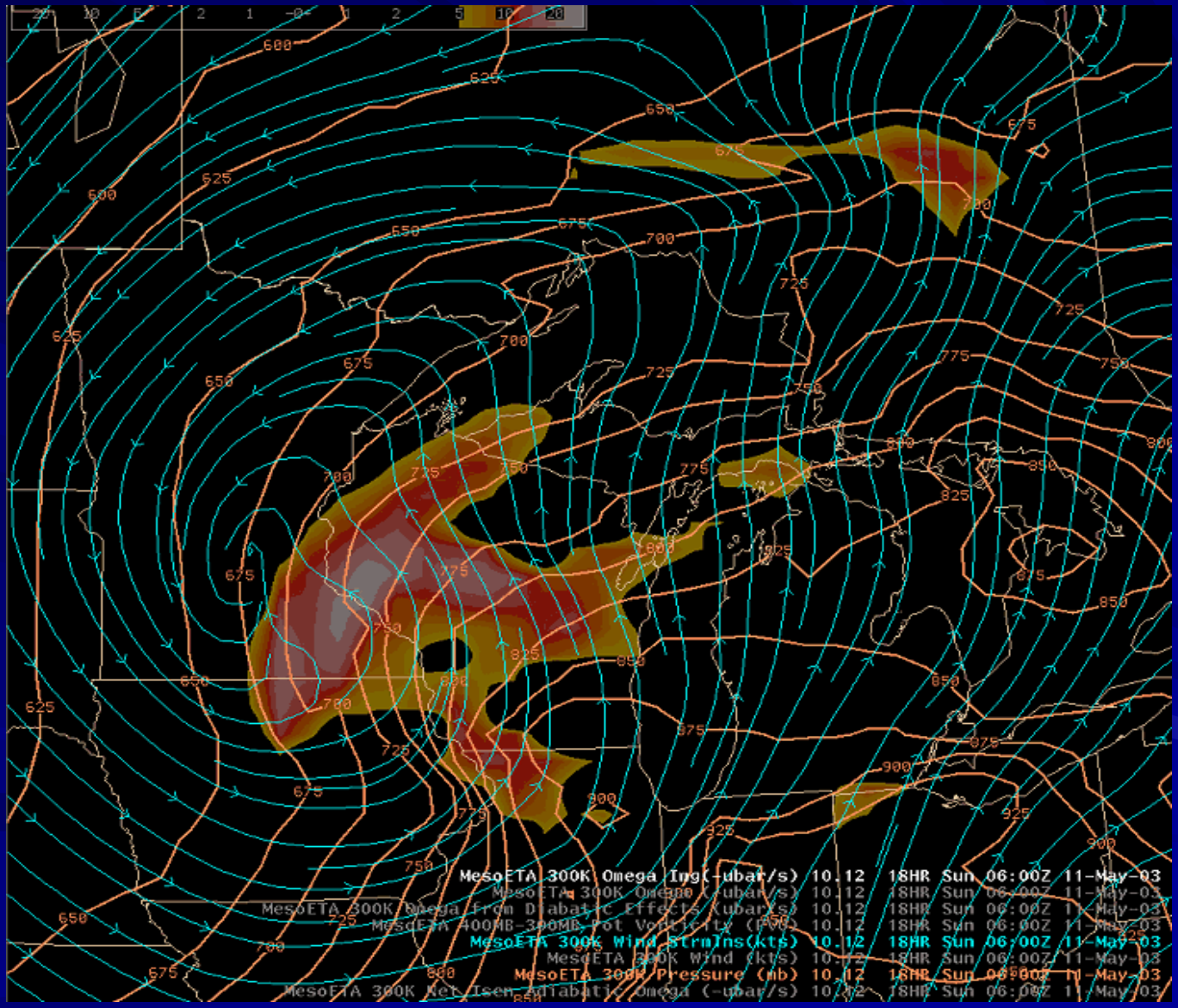
Composite Radar Loop 05/10/03 18z to 05/12/03 22z

(image interval 2 hours)

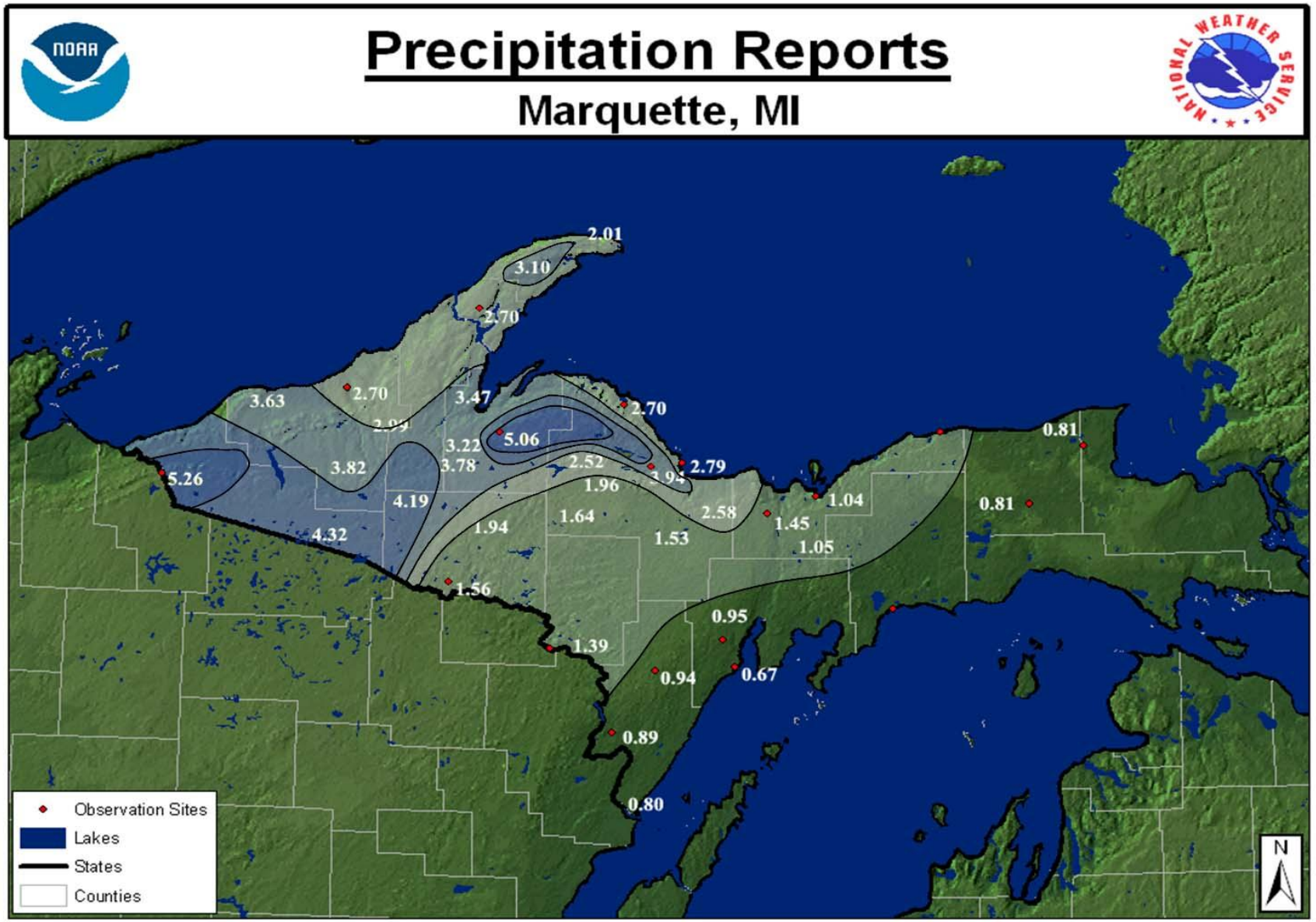


300K Surface 5/11/03 06z to 18z

Eta fcst 300K omega, pressure, streamlines (image interval 3 hours)

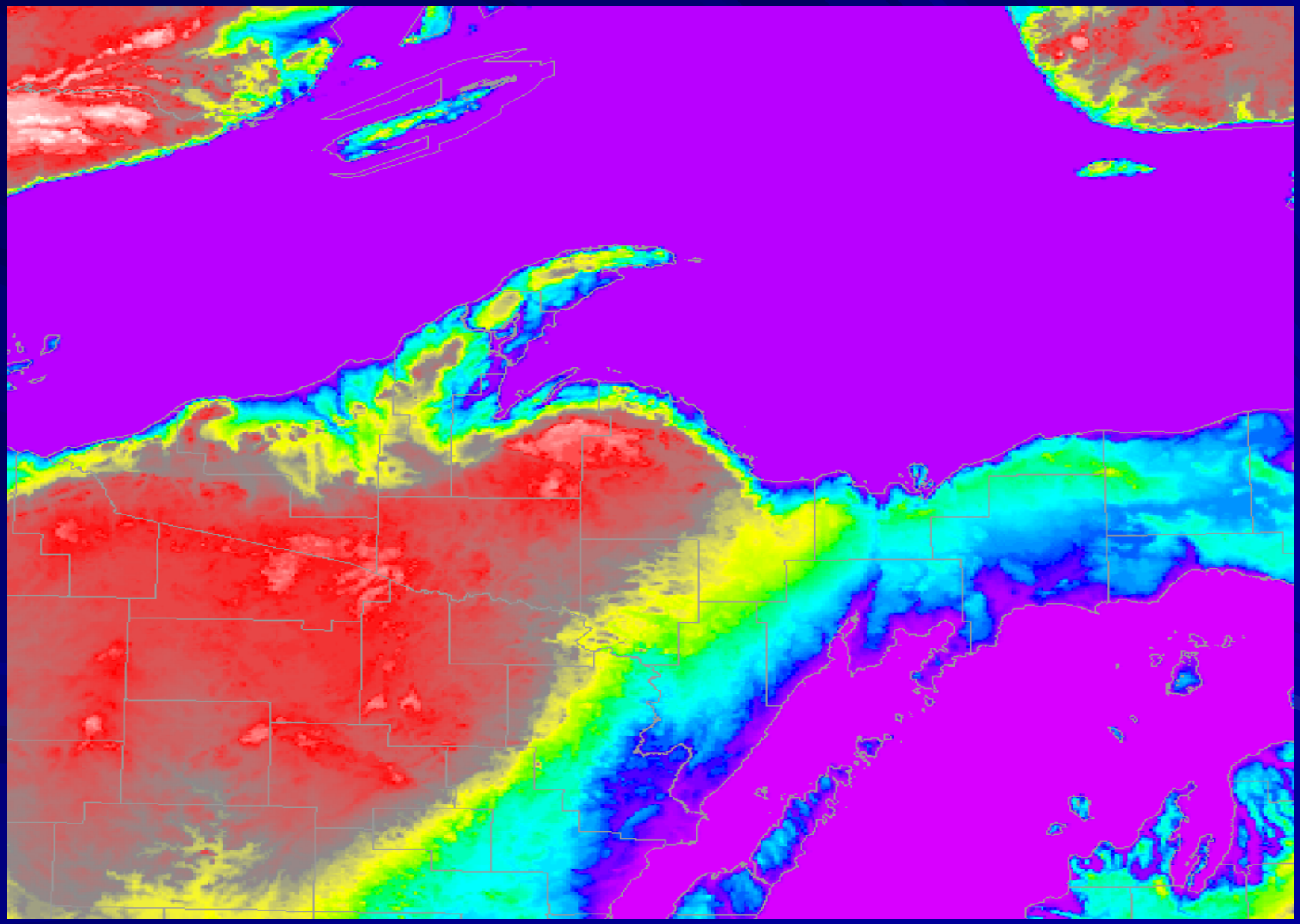


Precipitation from 5/10/03 to 5/13/03

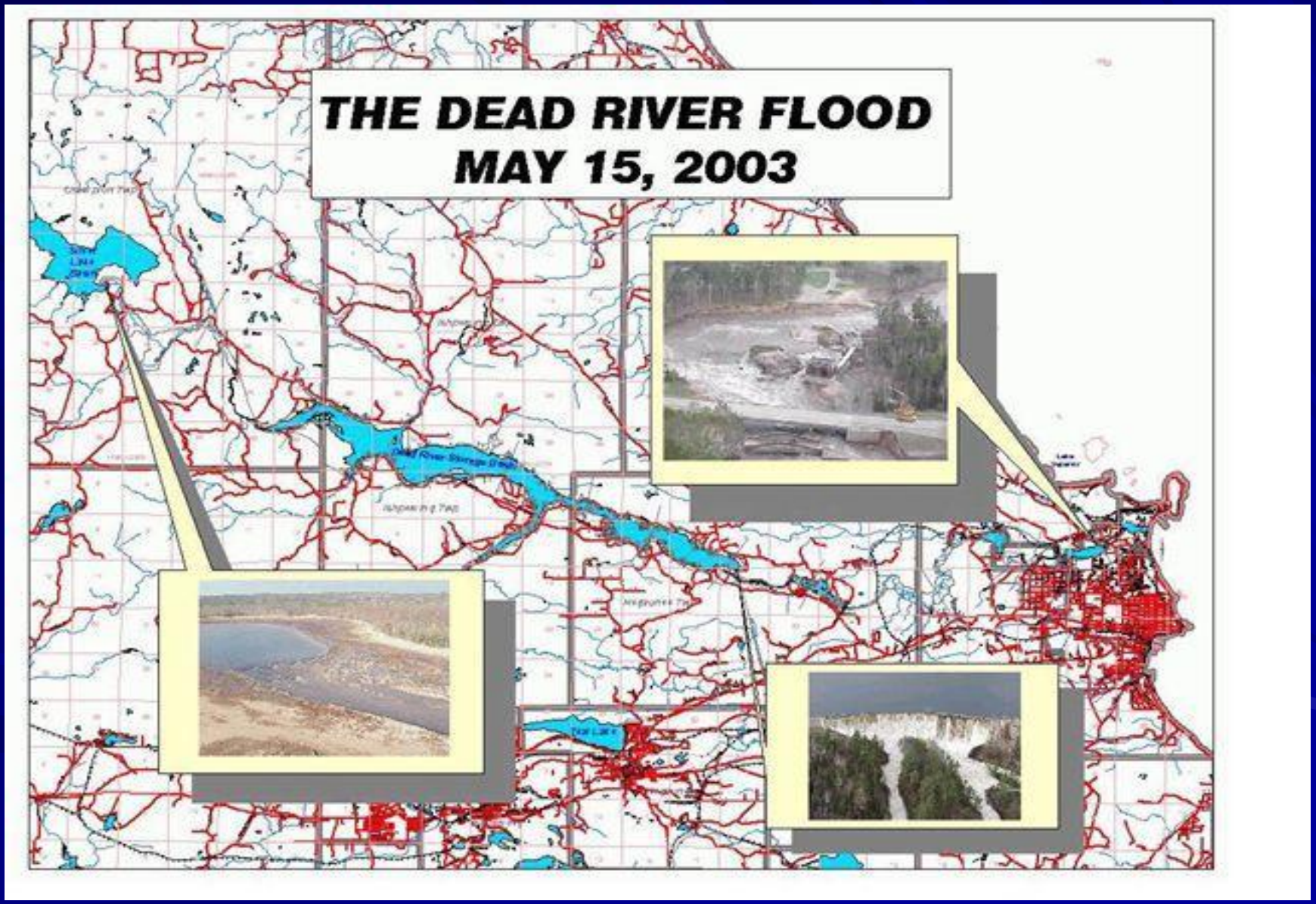


Upper Michigan Topography

min 578 ft (176m) max 1979 ft (603m)



Impacts from May 2003 heavy rain event



Heavy Rain Cases

Type 1

(24 Cases)

1969 06 27 00Z
1969 08 07 06Z
1970 09 21 12Z
1970 10 28 06Z
1972 06 20 06Z
1973 08 30 00Z
1976 08 11 18Z
1977 08 31 06Z
1978 08 16 00Z
1979 06 15 18Z
1979 07 25 06Z
1983 08 19 12Z
1983 09 04 18Z
1987 07 12 00 Z
1987 08 13 00Z
1990 06 12 06Z
1991 10 29 06Z
1993 07 06 00Z
1993 09 14 00Z
1983 10 11 18Z
1985 11 01 18Z
2002 04 24 12Z
2002 08 01 00Z
2003 09 14 00z

Type 2

(34 Cases)

1966 10 15 06Z
1970 05 31 00Z
1970 07 19 12Z
1970 09 02 12Z
1972 08 16 12Z
1972 09 26 06Z
1975 08 28 12Z
1977 07 14 12Z
1977 11 03 00Z
1978 07 20 00Z
1978 08 23 06Z
1978 09 11 06Z
1980 08 21 00Z
1981 06 14 06Z
1981 08 02 18Z
1982 08 03 12Z
1985 04 19 12Z
1985 09 03 06Z
1987 08 01 12Z
1988 08 02 12Z
1988 08 17 06Z
1989 06 07 18Z
1990 08 18 06Z
1991 07 29 06Z
1992 07 02 06Z
1999 07 09 06Z
1999 07 15 00Z
2000 07 27 06Z
2005 07 24 06Z
2005 09 19 18Z
2005 10 05 00Z
2007 09 04 12Z
2007 09 21 12Z
2007 10 06 06Z

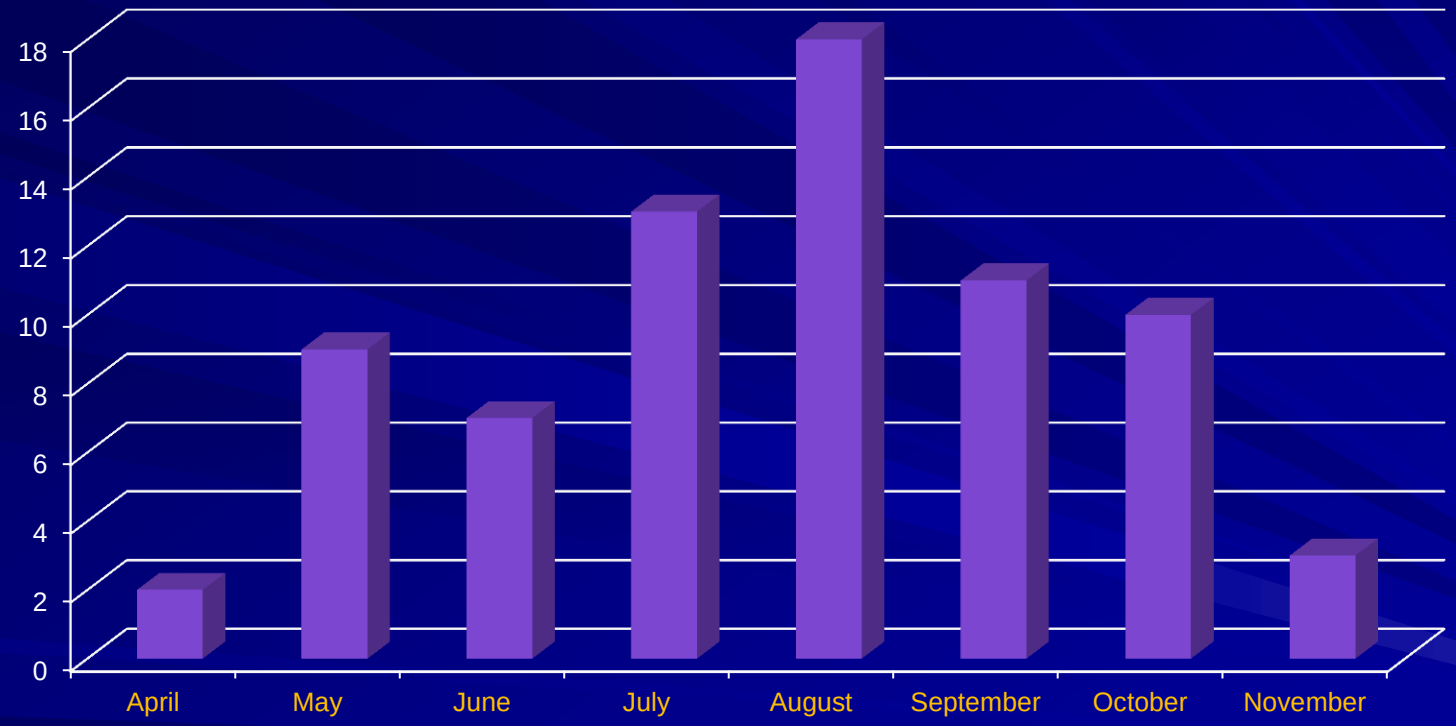
Type 3

(15 Cases)

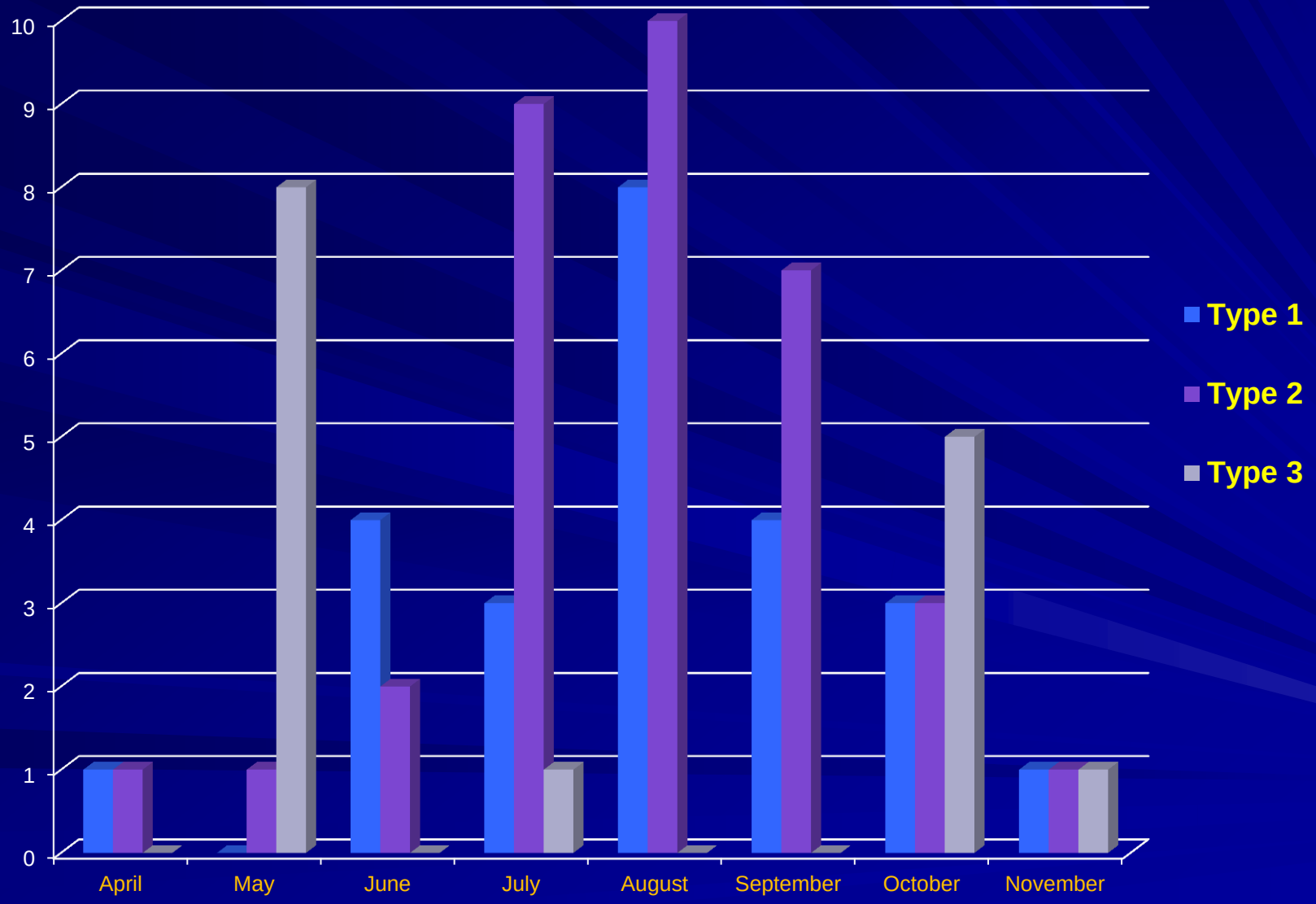
1967 10 08 12Z
1967 10 25 00Z
1973 05 01 12Z
1976 05 16 06Z
1978 05 13 00Z
1979 10 22 06Z
1982 07 11 06Z
1983 05 29 06Z
1985 10 04 18Z
1986 10 12 06Z
1992 11 21 00Z
2003 05 11 06Z
2004 05 23 18Z
2006 05 12 00Z
2009 05 28 06Z

Cases each month

(73 total)



Type by month

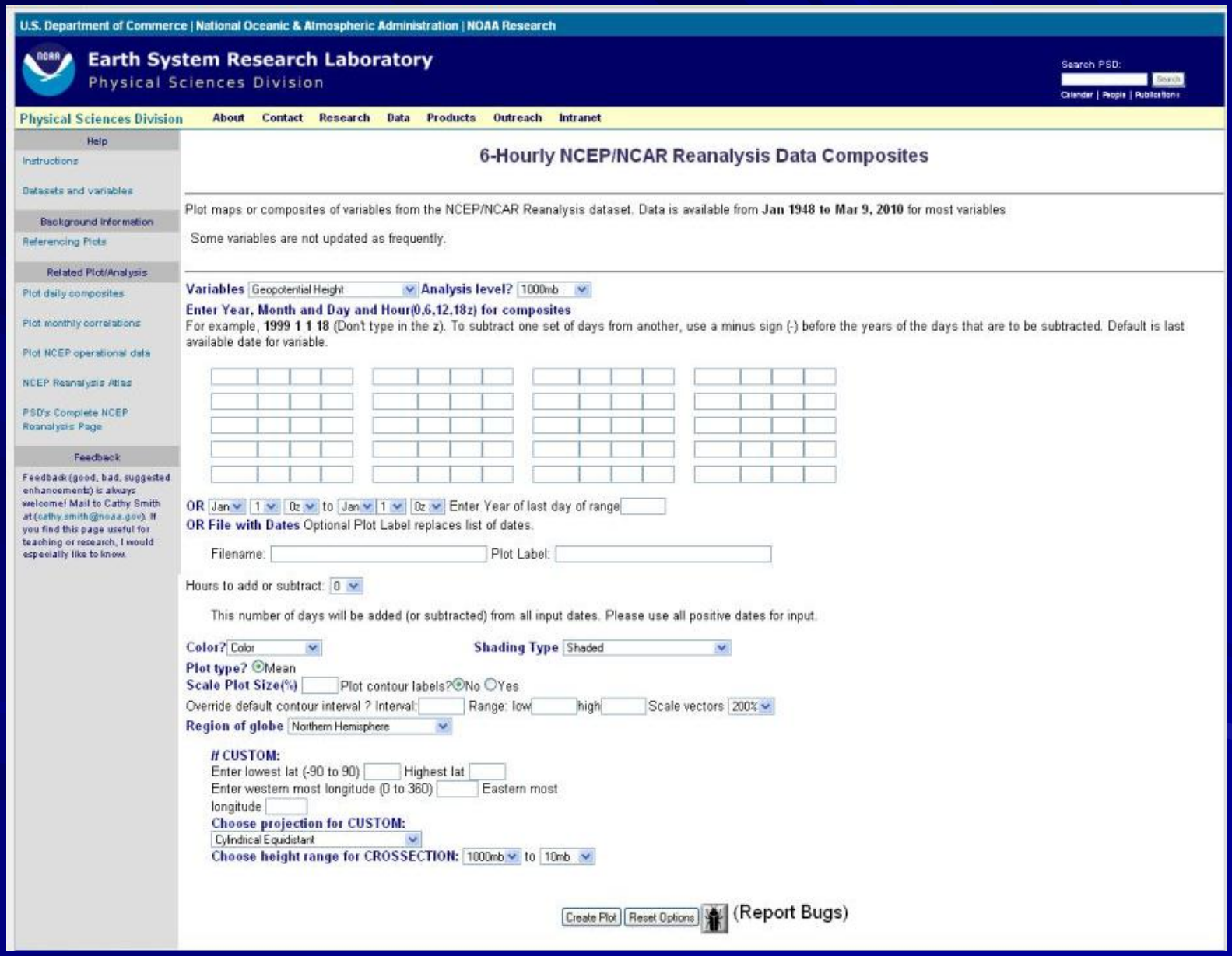


Moisture and instability characteristics

(maximum values during the 24 hour period)

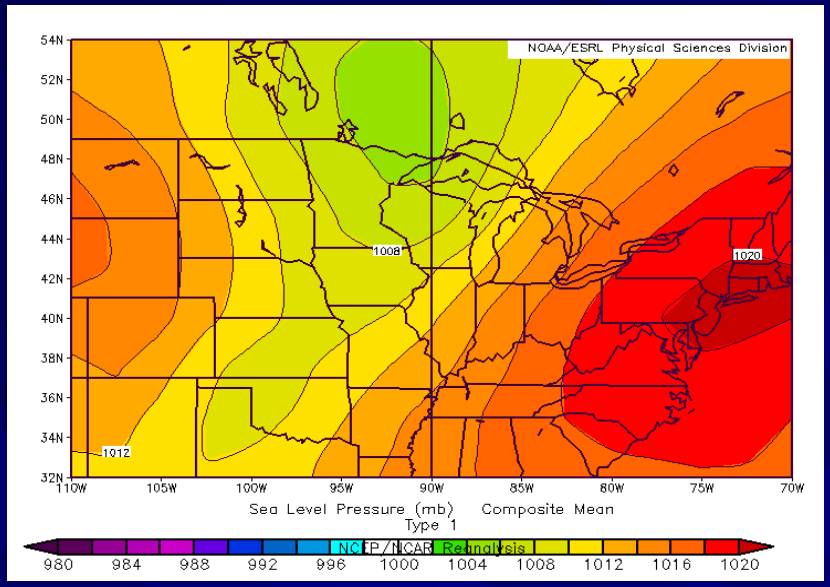
Type 1	
Mean precipitable water	39.9 mm
Standard deviation	6.7
Mean best 4-layer lifted index	-2.3
Standard deviation	2.3
Type 2	
Mean precipitable water	39.3 mm
Standard deviation	6.4
Mean best 4-layer lifted index	-2.5
Standard deviation	2.1
Type 3	
Mean precipitable water	29.5 mm
Standard deviation	6.2
Mean best 4-layer lifted index	2.4
Standard deviation	2.1

ESRL Composites web site

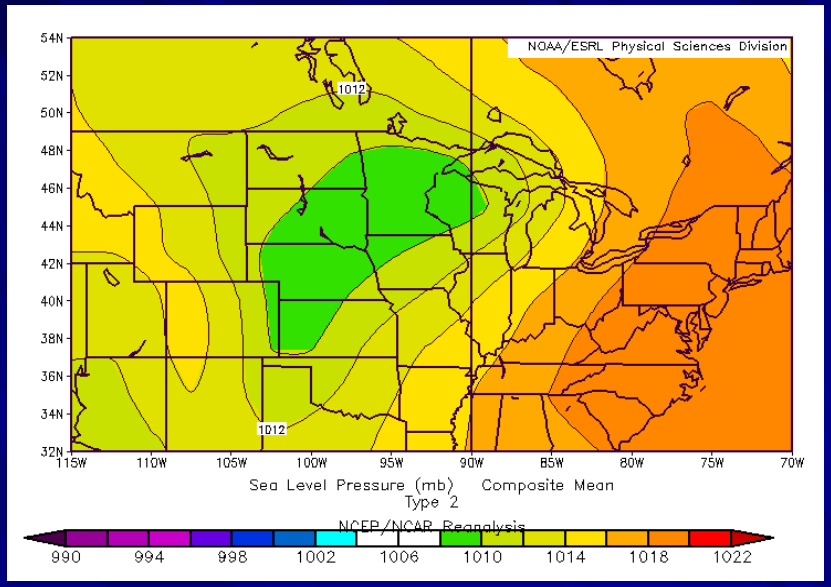


MSLP Composite Mean

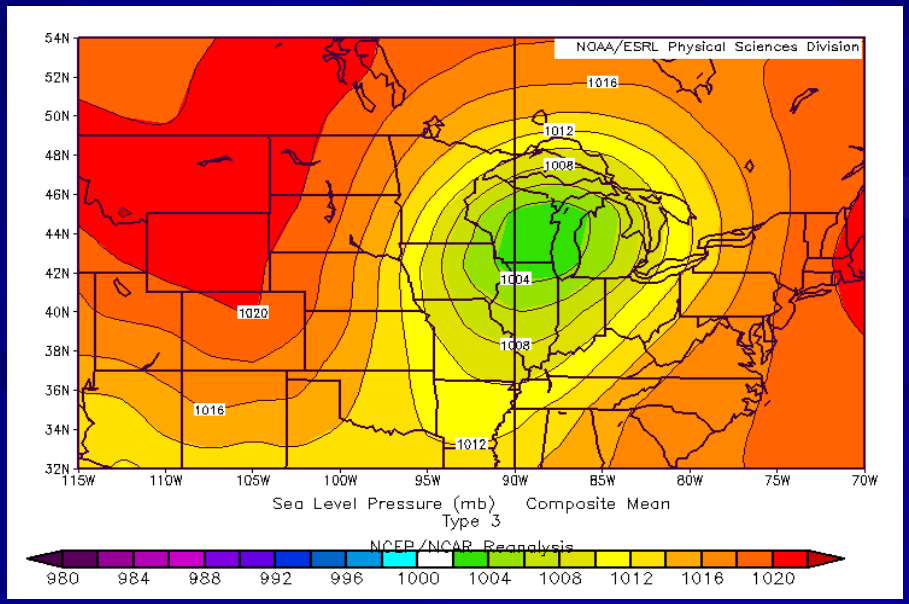
Type 1



Type 2

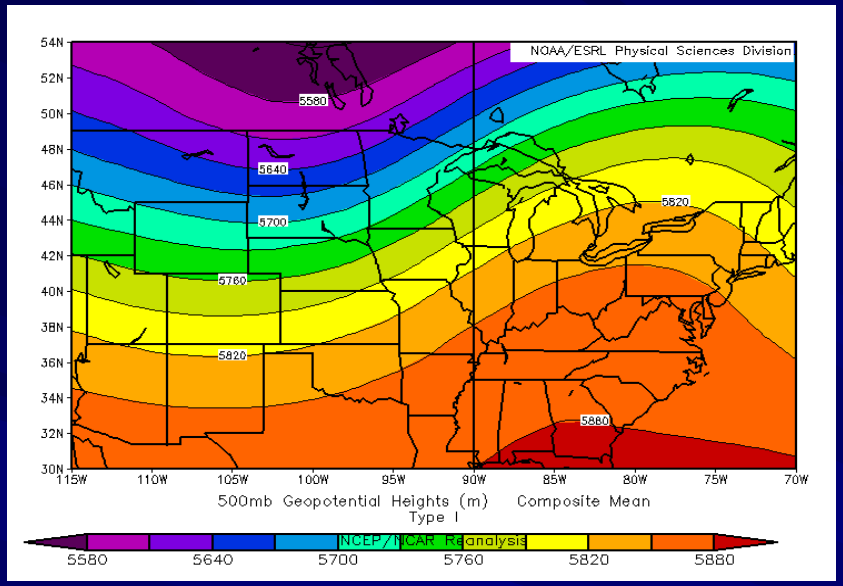


Type 3

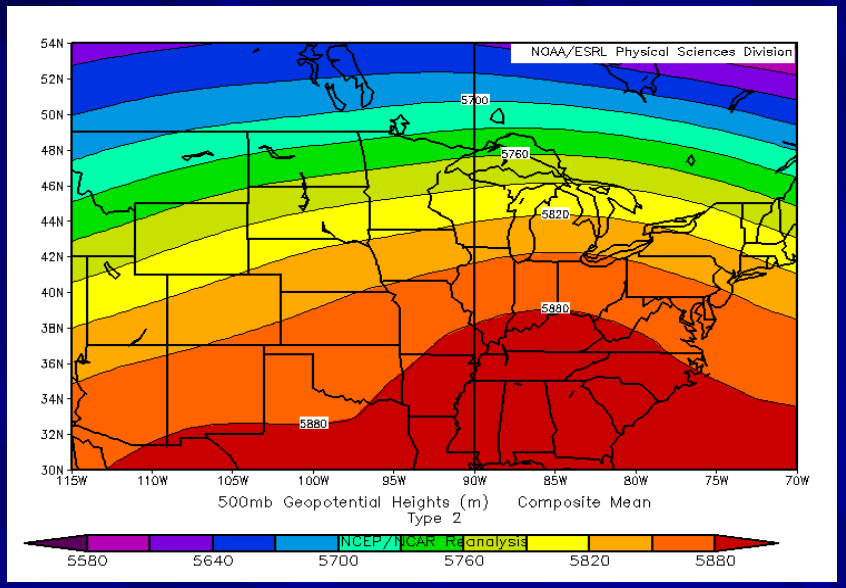


500 mb Composite Mean (m)

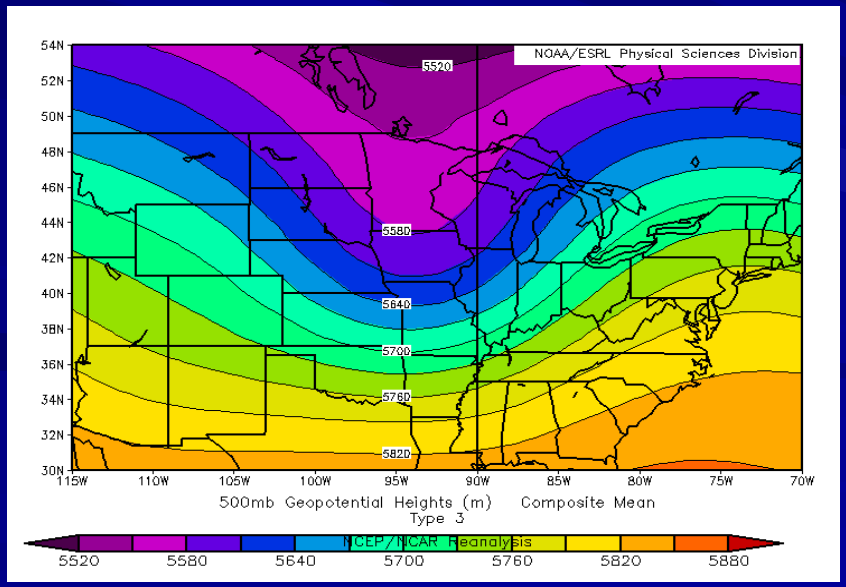
Type 1



Type 2

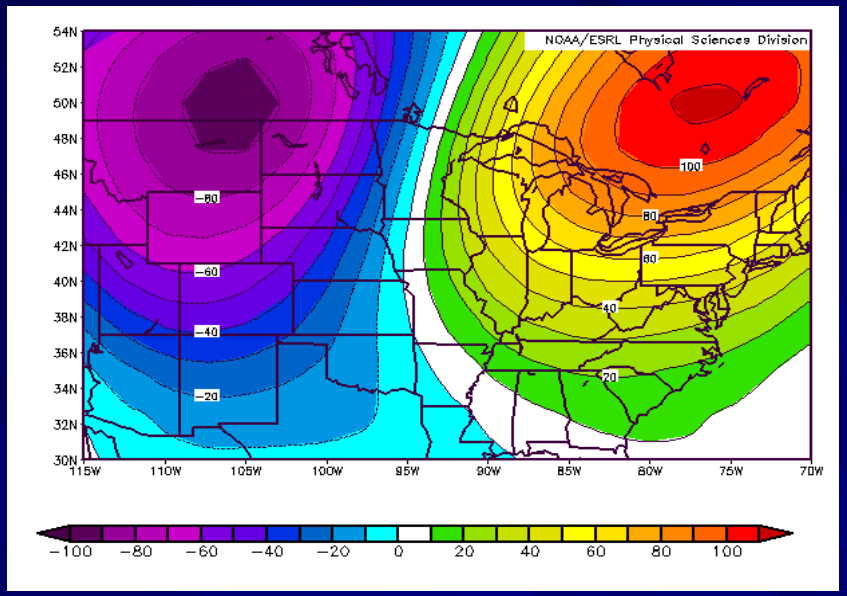


Type 3

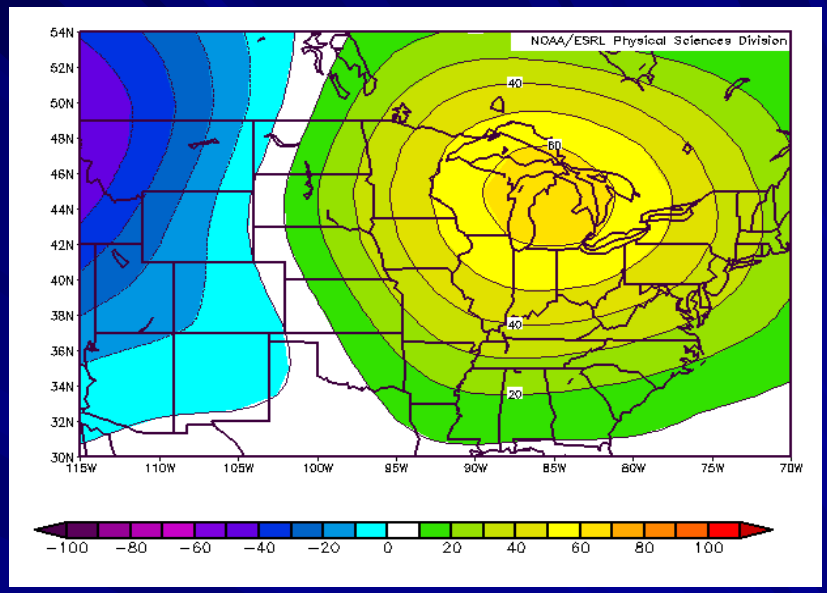


500 mb Composite Anomaly

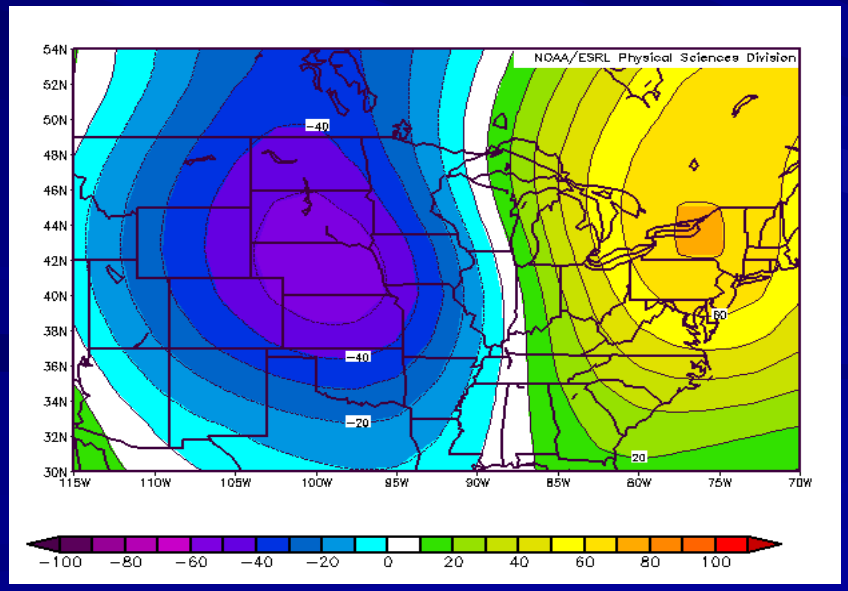
Type 1



Type 2

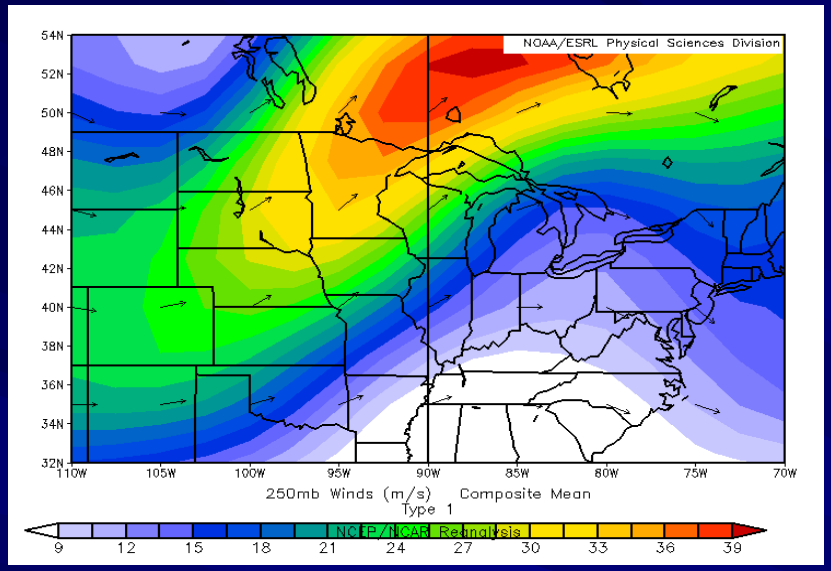


Type 3

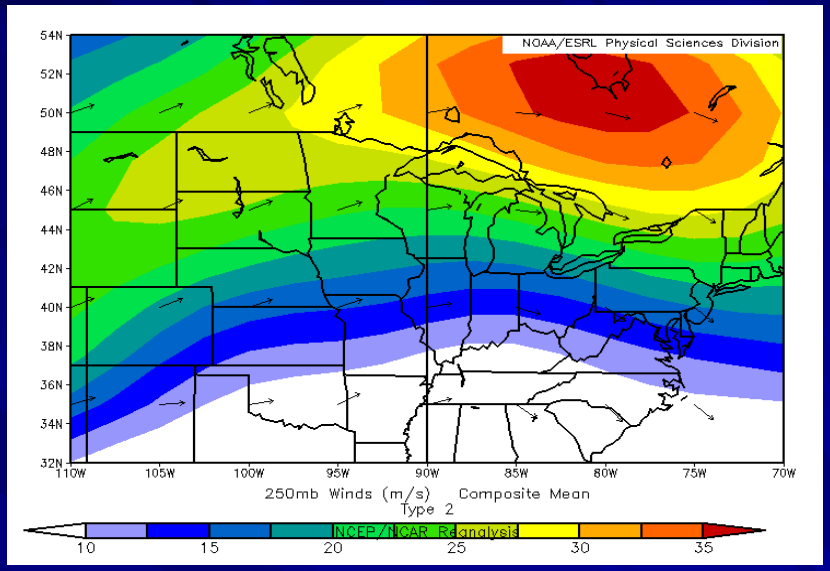


250 mb vector wind Composite Mean (m/s)

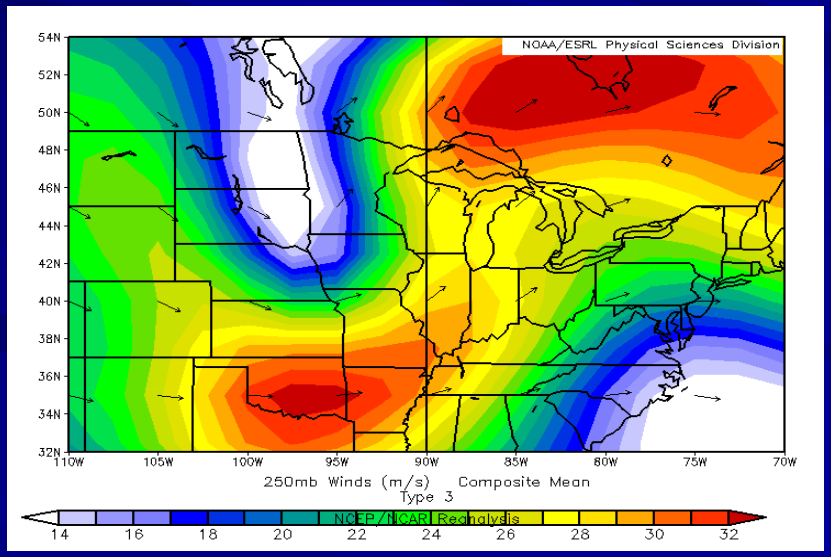
Type 1



Type 2

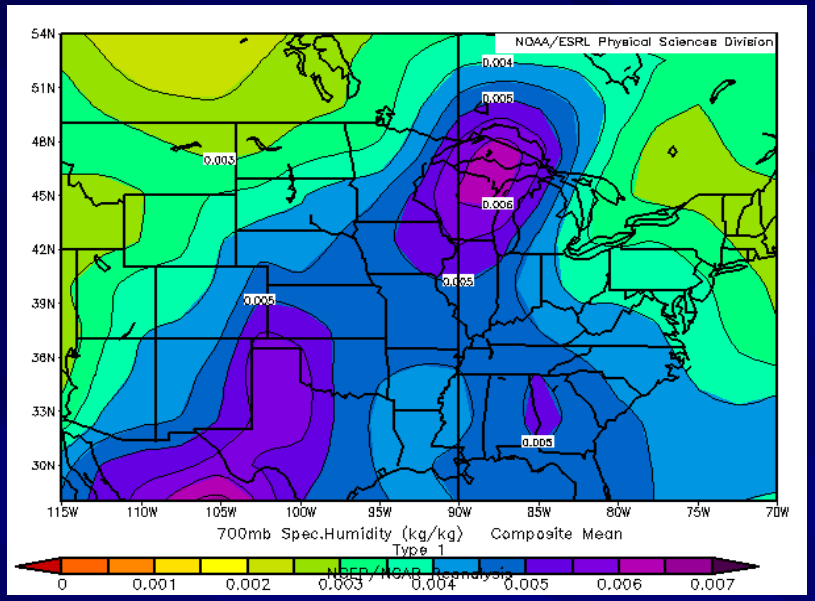


Type 3

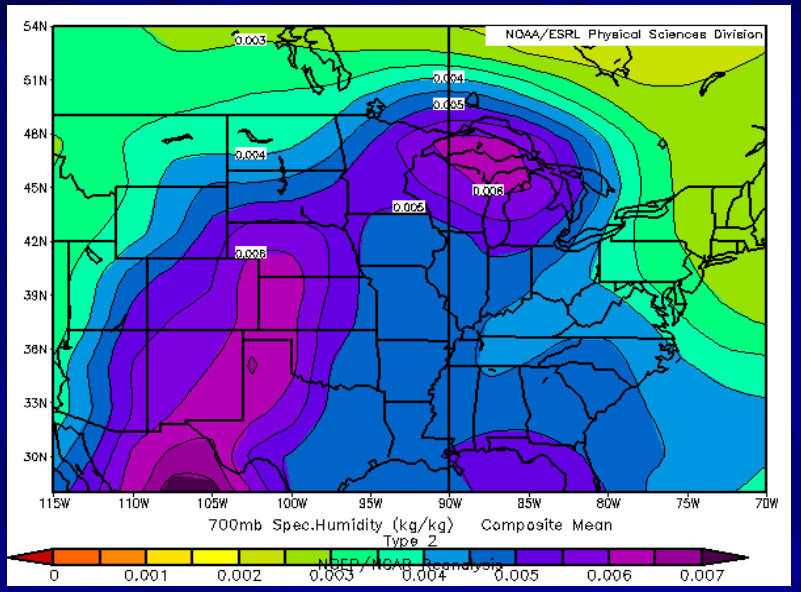


700 mb Specific Humidity Composite Mean (Kg/Kg)

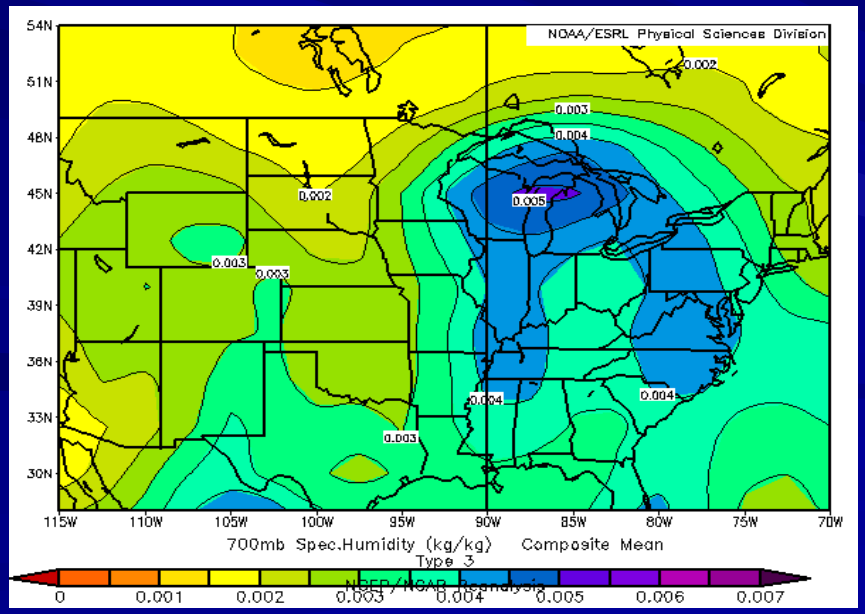
Type 1



Type 2

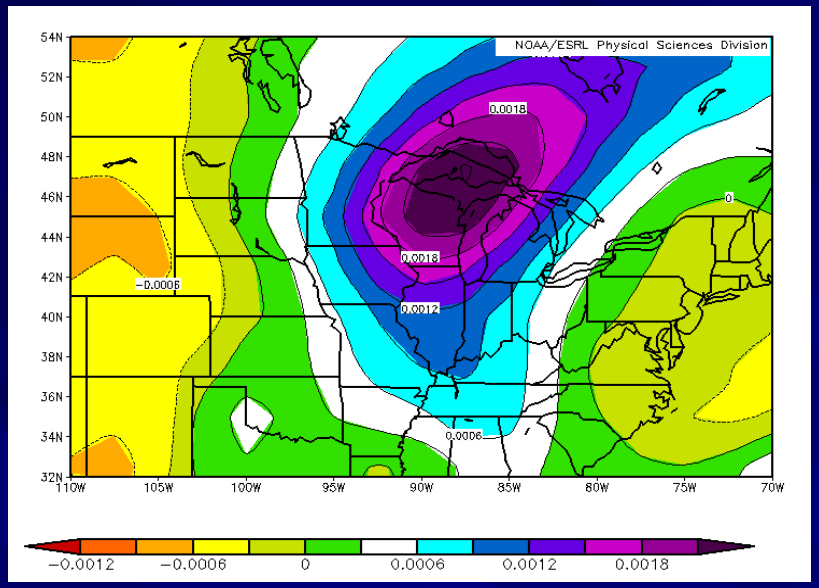


Type 3

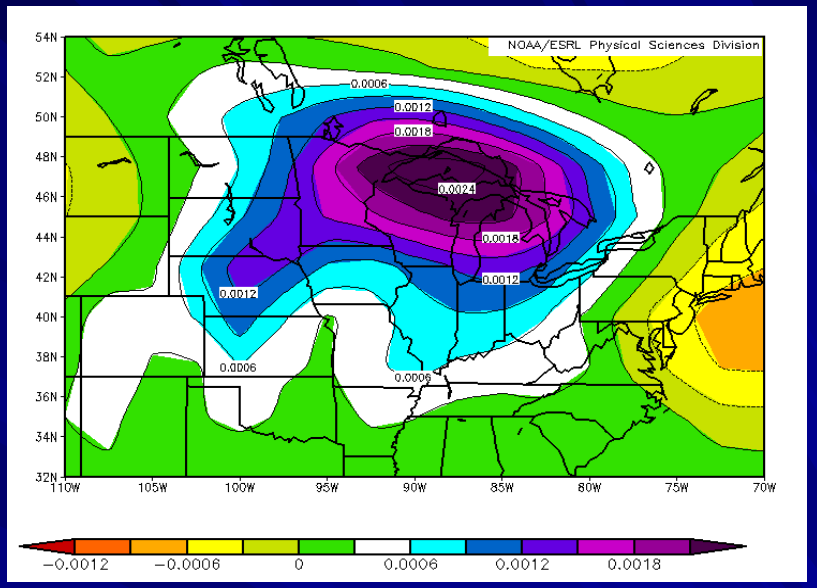


700 mb SH Composite Anomaly

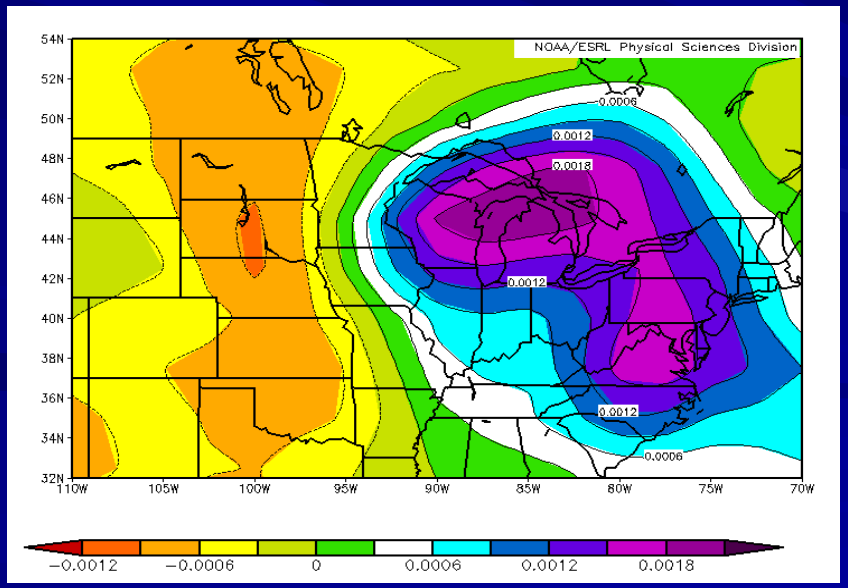
Type 1



Type 2

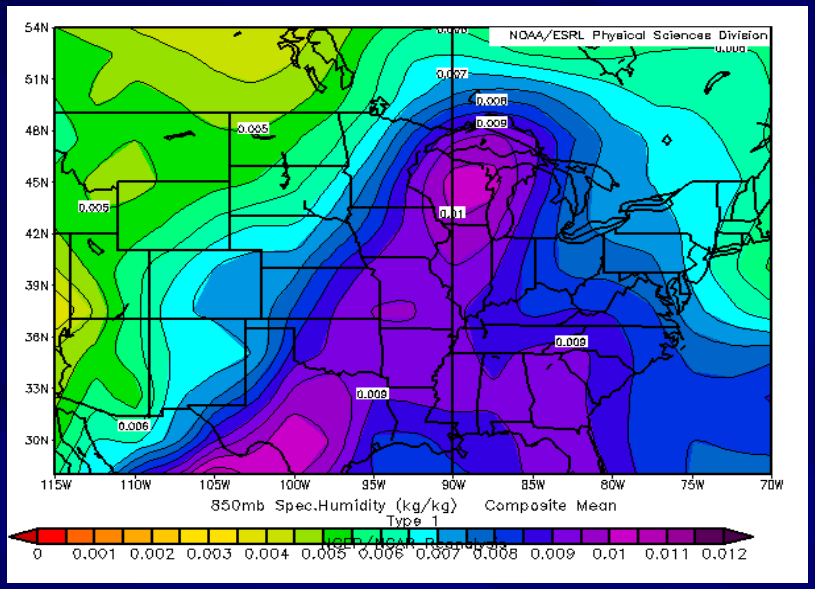


Type 3

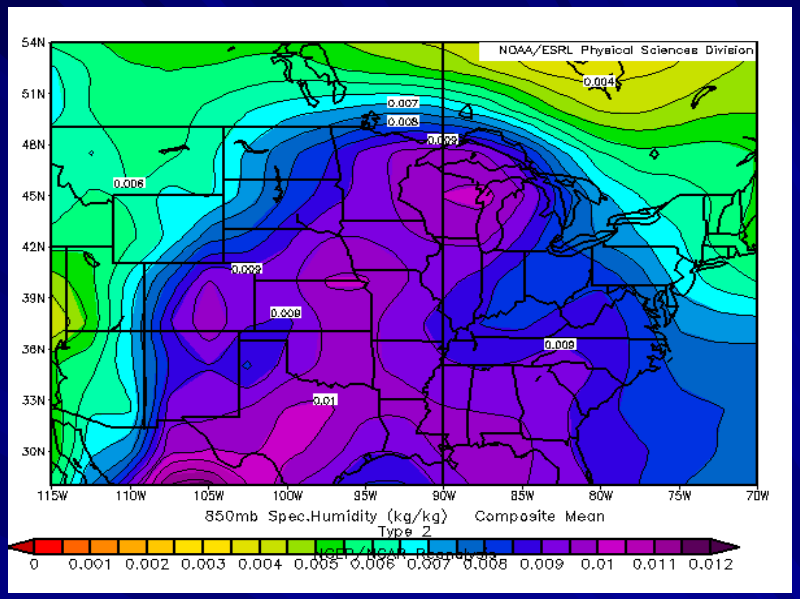


850 mb Specific Humidity Composite Mean

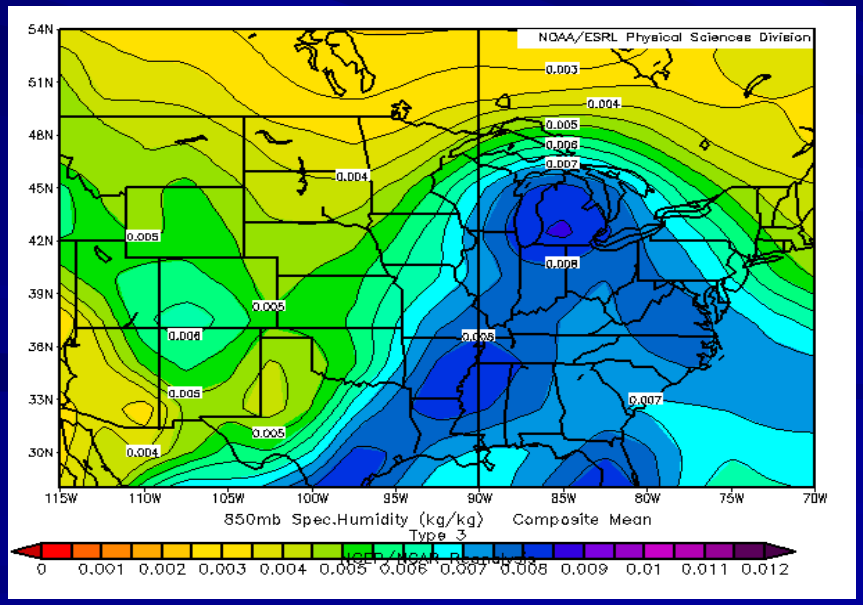
Type 1



Type 2

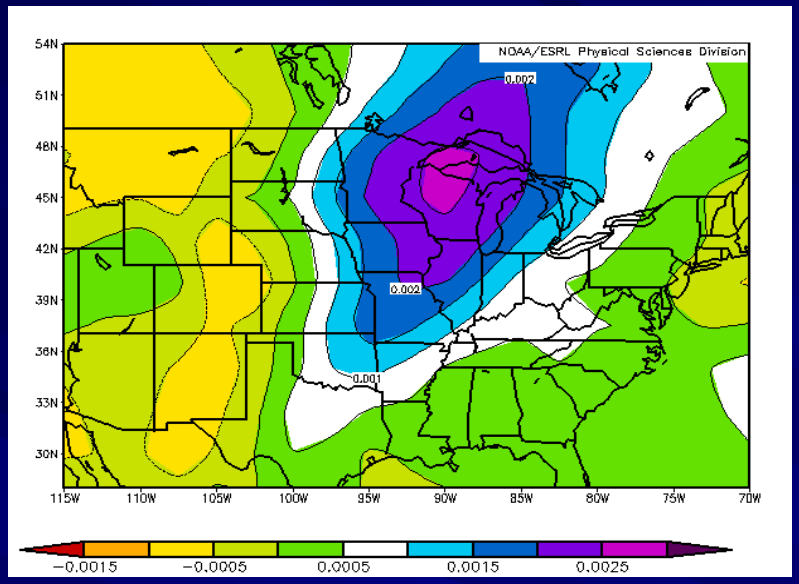


Type 3

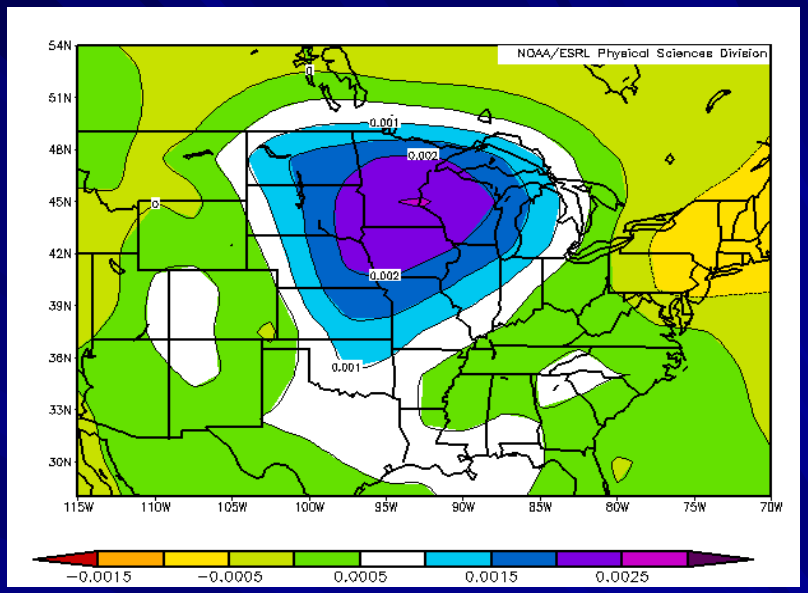


850 mb SH Composite Anomaly

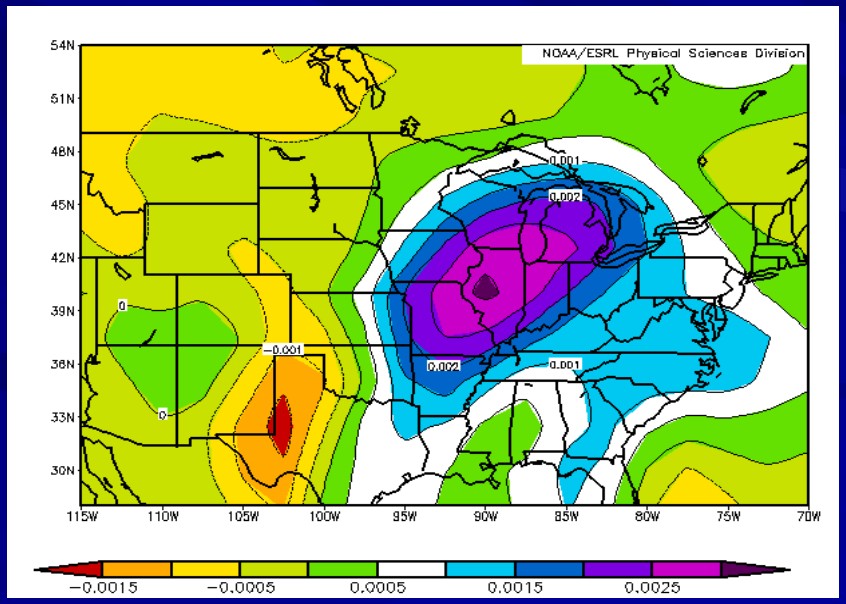
Type 1



Type 2

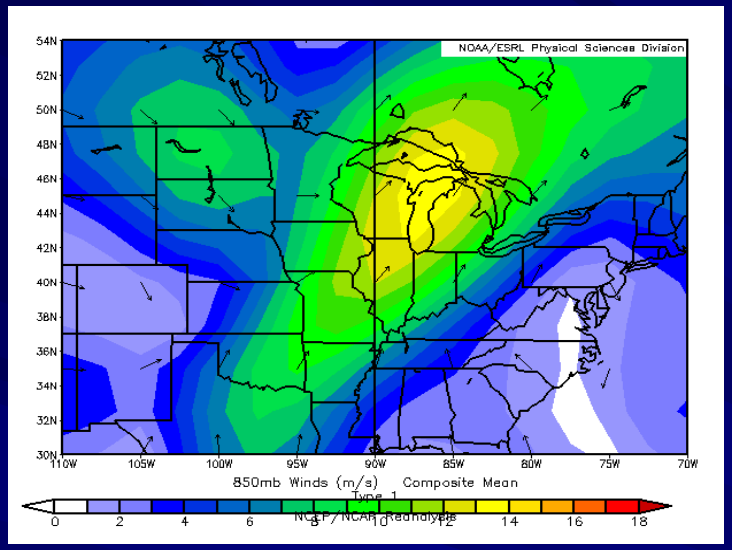


Type 3

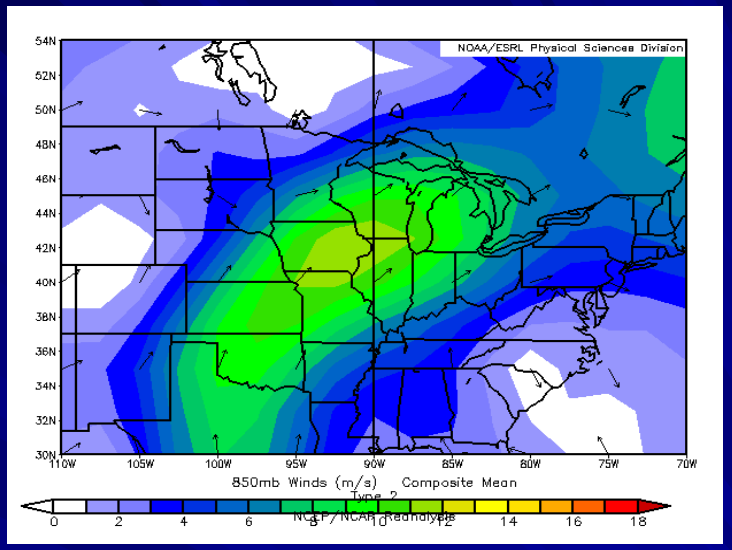


850 mb vector wind Composite Mean

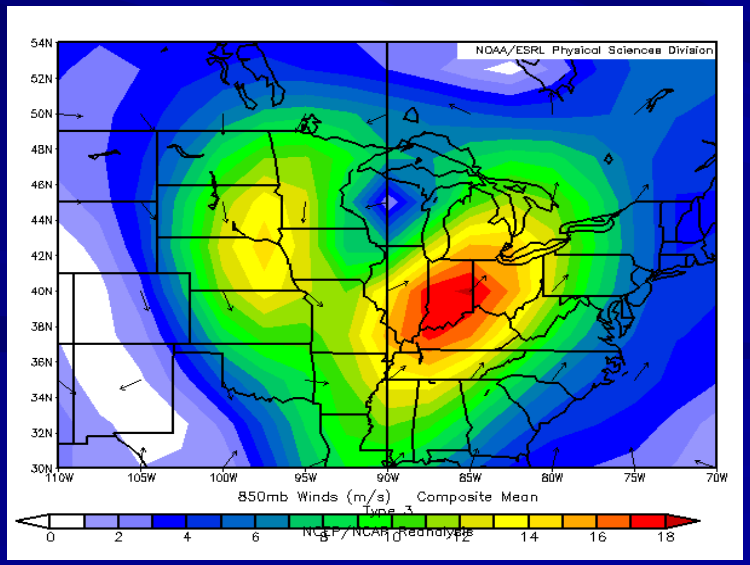
Type 1



Type 2

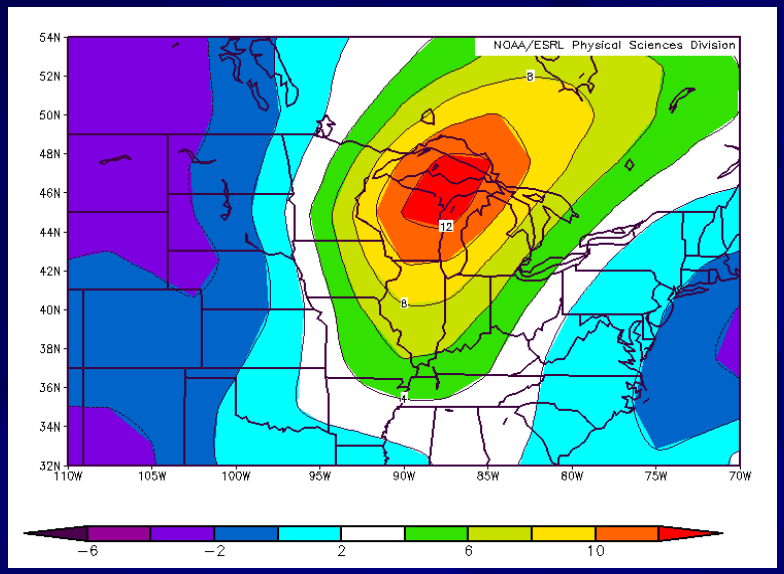


Type 3

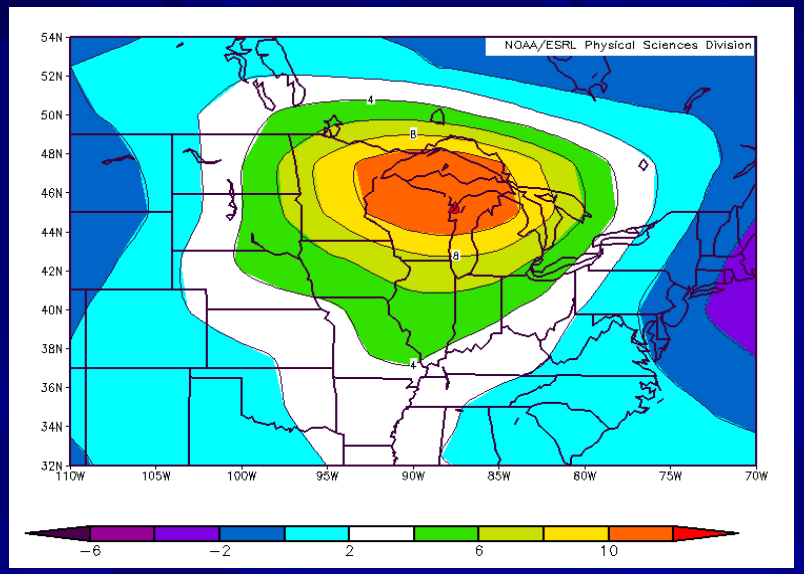


Precipitable Water Composite Anomaly (mm)

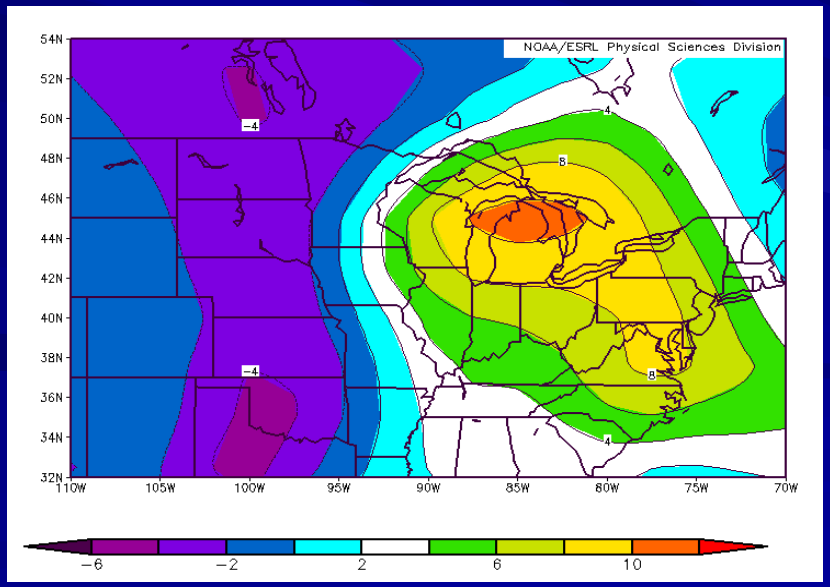
Type 1



Type 2



Type 3



Summary

- Heavy rainfall in Upper Michigan most likely in the late Summer and early Fall
- Inland locations showed a more distinct mid Summer maximum compared to locations where stable lake influences were more dominant
- Heavy Rainfall cases over Upper Michigan could be partitioned into three main pattern types
- Composite analyses of each pattern type showed familiar large scale forcing signals
- Low and Mid level moisture streams from the southwest were apparent
- Pattern recognition and awareness of heavy rainfall characteristics unique to the local area can increase success in forecasting these relatively rare events